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J. T. McNANEY
IMAGE STORAGE APPARATUS

2,805,360

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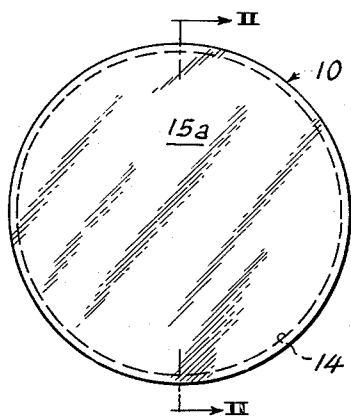


FIG. 1

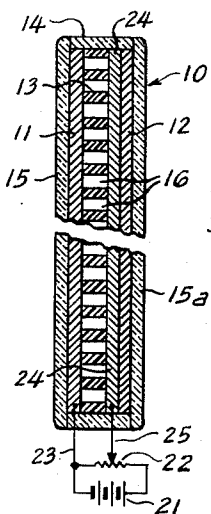


FIG. 2

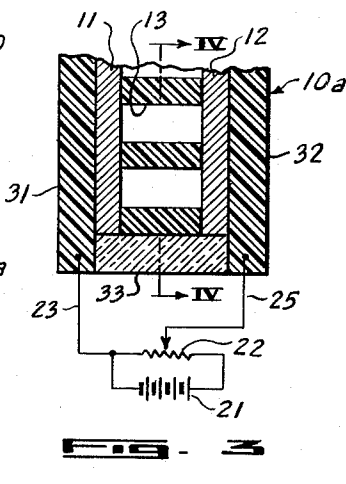


FIG. 3

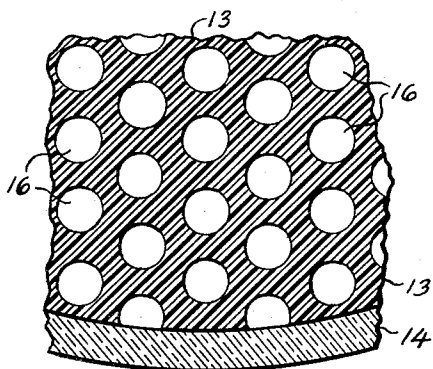


FIG. 4

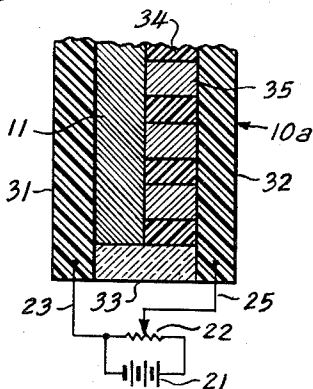


FIG. 5

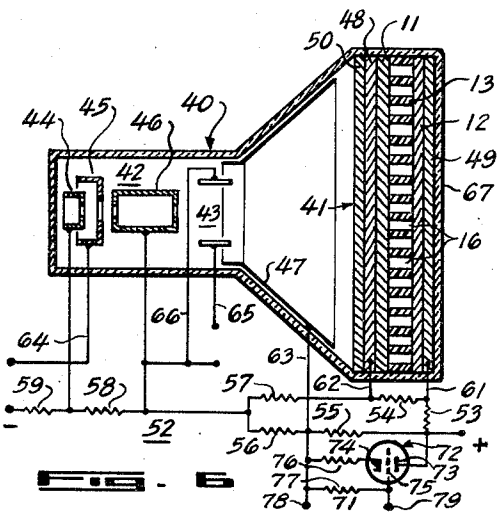


FIG. 6

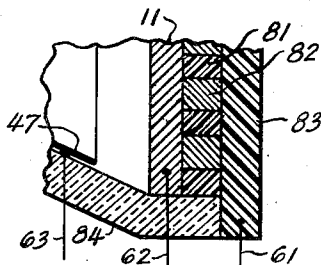


FIG. 7

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1

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7 Claims. (Cl. 315—11)

This invention relates to image display apparatus and more particularly to image display apparatus for storing and producing lasting image displays.

In many computer, facsimile, and other electronic systems in which output data is constantly changing, it has become increasingly necessary that accurate retention of this output information at any given instant be conveniently provided for extended periods of time. It is, therefore, an object of the present invention to provide apparatus for retaining and storing image information applied thereto at any given instant.

It is another object of the present invention to provide image storage apparatus adapted to simultaneously receive image information from a plurality of sources and produce sustained joint displays of the data applied at any given time.

It is another object of the present invention to provide image storage apparatus in the form of a cathode ray type storage tube having means for selectively erasing different images from the storage surface.

It is a further object of the present invention to provide a lightweight, inexpensive image storage device utilizing simplified construction for producing lasting displays of a size suitable for simultaneous presentation to a plurality of observers.

Other objects and features of the present invention will be readily apparent to those skilled in the art from the following specification and appended drawings wherein is illustrated a preferred form of the invention, and in which:

Figure 1 is a diagrammatic elevation view of a storage device illustrating an embodiment of the invention,

Figure 2 is a sectional view taken along line 2—2 of Figure 1,

Figure 3 is a fragmentary sectional view similar to Figure 2 but illustrating another embodiment of the invention,

Figure 4 is an enlarged sectional view taken along line 4—4 of Figure 3,

Figure 5 is a fragmentary sectional view similar to Figure 3 but illustrating still another embodiment of the invention,

Figure 6 is a sectional view of a cathode-ray tube embodying the invention, and

Figure 7 is an enlarged fragmentary view of a cathode-ray tube screen, similar to that shown in Figure 6, but illustrating another embodiment of the invention.

In its preferred embodiments, the present invention basically comprises a device having a plurality of layers including a radiation sensitive layer which emits electrons in response to image radiations directed thereon, an electron sensitive layer which responds to electron bombardment to produce image radiations in accordance with the electron image patterns, and a screen which transforms the total emission of the radiation sensitive layer into a plurality of isolated and discrete electron beams and also transforms the total radiations of the

2

electron sensitive layer into a plurality of isolated and discrete radiation beams. These laminae and the screen cooperate to produce area controlled radiation feedback from the electron sensitive lamina to the radiation sensitive lamina, such that electron emission is continuously regenerated from corresponding areas of electron sensitive lamina.

Referring to Figure 1, an image storage device is shown which includes an envelope 10 having a circular configuration in the particular construction illustrated. As illustrated in more detail in the sectional view of Figure 2, a lamina of radiation sensitive material 11, a lamina of electron sensitive material 12, and a screen 13 having a plurality of openings therein are positioned within envelope 10. The particular shape of envelope 10 forms no part of the present invention, and, as shown, it may take the form of a circular cylinder 14 having end faces 15 and 15a suitably sealed thereto. Thus, cylinder 14 and end faces 15 and 15a provide, in this embodiment, a sealed container capable of being evacuated. End portions 15 and 15a are preferably transparent to radiation patterns directed thereon and, where these radiation patterns are in the form of light, transparent glass or plastic may be utilized. The cylindrical member 14 may be produced from materials similar to those of end portions 15 and 15a, however, in some applications it may be desirable to make member 14 non-transparent and thereby limit radiations to those directed through faces 15 or 15a.

Radiation sensitive material 11 serves to transform radiation patterns directed thereon into corresponding electron images. Although the utility of the present invention is not limited to light radiations, for purposes of simplicity and clarification, the description hereafter will be given in terms of light. Accordingly, radiation sensitive material 11 may comprise material selected from the class of metals known as "alkali-metals" which characteristically emit electrons in the presence of light. Typical metals of this class are lithium, sodium, potassium, cesium, calcium, strontium, and the like. In accordance with the invention one of these light sensitive materials is formed in a continuous layer 11, positioned and arranged within envelope 10 to receive light patterns to be stored. A thin foil of the formed and effectively installed within envelope 10 in juxtaposition with transparent face 15 or, on the other hand, a lamina 11 of the proper material may be directly formed as a thin film upon face 15. Methods and techniques of preparing this light sensitive, electron emissive surface are well known in the art and many references are available, such as "Television" by V. K. Zworykin and B. A. Morton published in 1940 by John Wiley and Sons, Inc. Consequently, a light pattern directed through transparent face 15 serves to energize light sensitive lamina 11 whereupon lamina 11 emits electron streams in proportion to the light intensity and thereupon transforms and reproduces the light pattern into a corresponding integral electron image.

Screen 13 is positioned within envelope 10 and serves primarily to subdivide the integral electron image produced by light sensitive surface 11 into a plurality of independent elements to form a composite image in accordance with the integral image. Screen 13 may be a substantially planar member or lamina formed of a non-transparent material and is arranged to overlay portions of the continuous light sensitive surface 11. As shown in greater detail in Figure 4, screen 13 has incorporated therein a plurality of discrete areas or electron pervious portions 16, and with lamina 11 being a light sensitive material, screen 13 may be produced from opaque glass, plastic, ceramic, or like material in which areas 16 are actual openings extending therethrough, which are generally normal to the surfaces. The screen 13, which is

opaque intermediate the areas 16, is impervious to light transmission therethrough and may be said to be a light impervious portion which has formed therethrough the areas or electron pervious portions 16. Openings 16 are of a size sufficient to afford passageways for electron emission from surface 11 and also to afford transmission therethrough of light from electron sensitive material 12. Openings 16 may be formed in screen 13 by any of several suitable methods, such as molding, drilling, or photo-etching. In Figure 2, screen 13 is adjacent the continuous surface 11 and, as shown, is in abutting relation thereto. The opaque screen with its isolated transparent areas 16 serves to mask portions of the continuous light sensitive layer 11, transforms the integral electron image into a composite image formed within the areas 16 of screen 13, and openings 16, communicating between laminae 11 and 12 provide separate regenerative paths between corresponding areas of said laminae. Screen 13 also serves to restrict the direction of travel of the resulting electron streams forming the composite image and consequently restricts the area of regeneration within limits established by the respective transparent areas 16. Hence, with a light pattern directed through transparent face 15 and upon surface 11, a corresponding integral electron image is produced. Screen 13, in association with surface 11, breaks up the integral electron image into a plurality of independent image elements to form a composite image and channels each of the particular image elements toward predetermined areas on electron responsive lamina 12.

It will be apparent that the resolution of the composite electron image formed by the totality of the independent electron streams produced by the openings 16 of screen 13 is dependent upon the number of openings per unit area of the screen. Obviously, by increasing the number of openings in screen 13 resolution will be increased and the composite electron image transmitted through openings 16 will more nearly approximate the integral electron image formed on surface 11. As shown in the sectional view of Figure 4, apertures 16 are quite evenly distributed and arranged throughout the screen 13, however, the particular arrangement of the apertures 16 forms no part of the present invention and from the following description it will become readily apparent to those skilled in the art that the size, arrangement, and distribution of the apertures may be systematically organized for specific applications. For example, it may be desired to utilize apertures of graduated sizes and thereby provide variations in resolution over the surface of the screen. Furthermore, it has been determined that the path length travelled by the plurality of electron streams through the apertures 16 of screen 13 is immaterial to the operation of the device, however, the thickness of screen 13 should be sufficient to withstand the required potential gradients developed across it.

Although screen 13 has been described in terms of a surface having actual openings therein, it should be understood that other embodiments of the screen are contemplated. For instance, screen 13 may be in the form of a mosaic plate comprising a multiplicity of transparent, non-conductive particles isolated one from another by an opaque material. The resulting screen is functionally similar to screen 13 illustrated in Figure 4 and, when overlaying photoemissive surface 11, serves to convert the integral electron image into the composite image formed by the multiplicity of independent electron streams which are transmitted to lamina 12 via the isolated non-conductive particles. The transparent characteristic of the particles affords a regenerative feedback path from lamina 12 to lamina 11 to thereby re-energize exposed areas of the light sensitive surface 11.

Referring to Figure 2, the lamina of electron sensitive material 12, which serves to convert electron bombardment into corresponding energy patterns capable of re-actuating lamina 11, is positioned within envelope 10 and

is arranged to receive the various electron streams forming the composite electron image. In terms of light, lamina 12 may be produced from the generally used phosphors of zinc, cadmium, or calcium which are commonly termed fluorescent materials. As in cathode ray tube applications, fluorescent layer 12 is continuous and may be in the form of a thin film or coating which can be produced by the settling out of the phosphor material from a water suspension by methods familiar to those skilled in the art. Electron sensitive lamina 12 is arranged adjacent the transparent face 16 but may be formed directly upon face 16 by the settling process or by using a volatile liquid such as acetone with a small amount of binder and spraying the electron sensitive material on surface 16. Electron sensitive layer 12 is preferably coextensive with the apertured area of screen 13 and, thus, with a light pattern directed upon surface 11 an electron image is produced thereby which screen 13 subdivides into a multiplicity of independent electron streams corresponding to the image produced on surface 11 and directs each stream to a particular area on the fluorescent surface 12. Light is generated at surface 12 in response to the electron bombardment. Inasmuch as openings 16 allow the transmission of light therethrough, as well as electron streams, the light produced by a particular electron stream comprising the composite image is channeled back to surface 11 through the same opening through which the energizing electron stream travelled. In this manner regenerative feedback is provided to re-excite the portion of the continuous surface 11 which originally produced the electron stream in response to an element of the incident light image. Since the electron sensitive lamina 12 is arranged adjacent the transparent end portion 16 of envelope 10, the light image produced upon surface 12 will be visible to an observer looking through face 16.

Means are provided for establishing an electric field between laminae 11 and 12 whereby the elements forming the composite electron image are accelerated toward fluorescent lamina 12. As shown in Figure 2, the aforementioned means include a source of voltage, such as battery 21, across which is connected an adjustable voltage divider 22. The negative terminal of source 21 is connected through lead 23 to the light sensitive surface 11, and a positive potential is applied to fluorescent surface 12 by a conductive layer 24. As shown, the conductive layer 25 is connected to the voltage divider 22 by a lead 25. It will become apparent that means other than conductive layer 25 may be utilized to establish the field between laminae 11 and 12. For example, where electron sensitive lamina 12 is a good conductive surface, then the positive potential may be applied directly thereto by connecting lead 25 directly to lamina 12. However, as illustrated in Figure 2, conductive layer 24 is arranged adjacent to and coextensive with the light sensitive layer 12. Layer 24 is preferably a very thin transparent coating or film of material such as silver, cadmium, or aluminum, and the various electron streams which make up the composite electron image have sufficient energy to penetrate layer 24 and impinge upon the electron sensitive lamina 12. Since layer 24 is transparent, the light generated by lamina 12 also penetrates layer 24, passes through areas 16 in screen 13, and re-energizes the associated surface elements of lamina 11. It, therefore, becomes apparent that the presence of conductive layer 24 does not adversely affect the operation of the device. However, where layer 24 is utilized, its position with respect to lamina 12 is immaterial and they may be transposed without materially affecting the operation of the device.

In operation, a light pattern is directed through transparent face 15 and onto the light sensitive layer 11 thereby causing each incremental area illuminated by the light pattern to produce an integral electron image which has a pattern and density that corresponds in detail to the pattern and density of the incident light image. The

electric field established across laminae 11 and 12 serves to direct the integral electron image as a unit toward the electron sensitive lamina 12. However, screen 13, as illustrated in Figure 2, is interposed between the layers and masks portions thereof. Hence, the integral electron image is dissected into a plurality of independent image elements by the configuration of screen 13 to form the composite electron image. Each of the plurality of discrete electron beams forming the composite image has a magnitude proportional to the intensity of the light falling upon the corresponding area of layer 11 underlying an opening 16 in screen 13. Each of the electron streams flowing from layer 11 is confined within an opening 16 of screen 13 and forms an element of the integral image generated at lamina 11 in response to the incident light image.

The electric field applied to the electron beams traveling through areas 16 in screen 13 imparts sufficient energy to the beams to cause them to penetrate conductive layer 25 and impinge upon electron sensitive lamina 12. In response to bombardment by the various electron streams, areas of lamina 12 in the path of the streams are caused to generate light—the intensity and pattern of which is proportional to the intensity and pattern of the respective electron beams. The areas of light and shadow thus produced on lamina 12 form a light image which is generally similar to the incident light pattern directed through transparent face 15 onto lamina 11. The light image produced on lamina 12 is visible through transparent face 16 of envelope 10.

Regenerative action is established which serves to sustain the secondary light image developed on lamina 12. This regeneration is realized by the feedback of light from lamina 12 through the transparent conductive layer 24 and the openings 16 of the collimating screen 13 and onto the light sensitive layer 11. It, therefore, becomes apparent that a plurality of regenerative feedback paths are provided and the light from each element of the secondary light image is confined within the same opening of screen 13 as that in which the corresponding electron beam which produced the light was confined. The electric field impressed across laminae 11 and 12 may be utilized to control, in effect, the degree of regeneration. By varying the potential applied to conductive layer 24, control may be indirectly exerted over the amount of light feedback to lamina 11 and this consequently provides regulation of the intensity of the light image displayed on surface 12 and viewable by an observer through member 12.

In Figure 3 is illustrated a display device including light sensitive layer 11, electron sensitive layer 12, and screen 13 all of which are structurally and operationally similar to those described hereinbefore. Elements 11, 12 and 13 are enclosed within an envelope 10a which comprises transparent faces 31 and 32 and an annular member 33 to which faces 31 and 32 may be suitably sealed. The faces 31 and 32 are preferably constructed of a transparent material such as glass or plastic although other materials that are optically transparent may be used. Assuming that faces 31 and 32 are glass and an electrically non-conductive material, faces 31 and 32 are made electrically conductive. The electrically conductive coating applied to the glass surface is also substantially transparent optically. A preferred method of providing the transparent conductive coating is known as iridizing and is fully described in U. S. Patent 2,522,531 entitled, Method of Producing Electrically Conductive Coatings on Glass and Mica Sheets. The unitary structure of transparent faces 31 and 32 comprising the glass surface and a transparent conductive layer of iridized tin is commercially available and is generally known as "electrically conductive glass." Alternatively, transparent conductive faces 31 and 32 may include a glass surface and a conductive layer applied thereto by a vacuum-evaporation

process, such as a layer of evaporated aluminum, or by a sputtering process, such as a layer of sputtered gold.

As shown, an electric field is established between faces 31 and 32 by direct interconnection of source 21 through voltage divider 22 and leads 23 and 25 to surfaces 31 and 32. Operation of the device illustrated in Figure 3 is similar to that described hereinbefore. A pattern of light and shadow is directed through the transparent face 31 and onto the light sensitive member 11 whereby an integral electron image is generated which is proportional to the light and shadow of the incident light pattern. The voltage applied to the conductive faces 31 and 32 from the source 21 establishes the electric field across the continuous laminae 11 and 12 and serves to direct the integral electronic image toward lamina 12. Screen 13 is interposed between the laminae and overlays portions of each, hence, the integral electron image produced on layer 11 is broken up into a multiplicity of independent image elements in accordance with the opening 16 of screen 13. Each of the image elements thereby produced has a magnitude proportional to the intensity of the light falling upon the corresponding area of layer 11 underlying the particular opening in the screen. As stated hereinbefore, the electric field established between laminae 11 and 12 serves to accelerate the various elements forming the composite image toward the electron sensitive layer 12, and screen 13 with the electron pervious areas 16 therein serves not only to transform the integral electron image into the elements forming the composite image but also aids in preventing spreading and scattering of the electron image elements in traveling from lamina 11 to lamina 12. In response to bombardment by the various electron streams, areas of the continuous surface 12 in the path of the streams are caused to generate light. The light pattern generated by lamina 12 in response to the independent electron streams forming the composite image and channeled to the electron sensitive lamina 12 via the openings of screen 13 serves to reenergize corresponding portions of surface 11. Energy feedback to lamina 11 is focused by the openings 16 to the particular element of layer 11 from which the energizing electron stream originally emanated. This area restricted feedback is regenerative and serves to produce a sustained composite light image on layer 12 which may be viewed through the transparent end face 32.

As illustrated in Figure 5, a continuous light sensitive lamina 11, screen 34, and lamina of electron sensitive material 35 are positioned within the envelope 10a, which includes transparent conductive faces 31 and 32 and the cylindrical member 33 suitably connected between the faces 31 and 32 to provide an enclosed container. A voltage is impressed across laminae 11 and 35 by the connection of leads 23 and 25 to the conductive portion of transparent faces 31 and 32. Thus, with a light pattern directed through end face 31 and onto the continuous light sensitive layer 11, an integral electron image is produced by layer 11 which has a pattern corresponding in detail to the incident light pattern. Screen 34 is generally similar to screen 13 described hereinbefore and illustrated in Figure 4 and is preferably a planar member of non-transparent material which has a plurality of small openings therein, such as the openings 16. The lamina of electron sensitive material 35, which serves to transform electron images into light, may comprise one of the fluorescent materials mentioned hereinbefore, however, in this display device the fluorescent lamina 35 is arranged within the openings of screen 34. Thus, it becomes apparent that within screen 34, lamina 35 is a discontinuous layer and is more in the form of isolated islands of electron sensitive material surrounded by the opaque areas of screen 34 and together the screen and fluorescent material constitute a continuous layer. The electron sensitive material may be established within the openings of screen 34 by the well known process of settling out of the phosphor material from a water suspension. Screen 34 is arranged adjacent the continuous light sensitive surface 11,

and the opaque portions of the screen serve to mask out portions of lamina 11 and prevent scattering of light and uncontrolled light feedback from the individual areas of surface 11. Hence with a light pattern directed onto lamina 11, an integral electron image is generated which energizes the elements of lamina 35 to produce a composite light image comprising a plurality of light elements produced by the energized elements of lamina 35. The composite image produced by layer 35 comprising the multiplicity of elements serves to re-energize corresponding portions of the light sensitive surface 11 which are beneath the islands of electron sensitive material within the openings of screen 34 and light generated by one element of lamina 35 is channelled by the surrounding opaque portions of screen 34 to a particular incremental area of surface 11. It becomes apparent that the feedback from elements of fluorescent layer 35 to associated areas of layer 11 is regenerative. This area controlled regenerative feedback serves to produce a sustained composite light image on layer 35, and being arranged adjacent the transparent end portion 32 of envelope 10a, the light image produced thereon will be visible to an observer. Although envelope 10a is illustrated in the drawings and described in detail in conjunction with the description and operation of lamina 11, screen 34, and electron sensitive lamina 35, shown in Figure 5, it is understood that envelope 10 and suitable means for impressing the voltage across the laminae as shown and described in connection with Figure 2 may be effectively utilized.

Referring now to Figure 6 a cathode ray type image storage device is illustrated which includes an evacuated envelope 40 enclosing a storage screen 41 to be described in detail hereinafter, an electron gun 42 for generating, focusing, and accelerating a beam of electrons toward storage screen 41, and a set of deflection plates 43 for causing the electron beam to be deflected to various areas of screen 41.

The electron gun 42 positioned at an end of envelope 40 preferably comprises a cathode 44, a control electrode 45, and an accelerating anode 46. Associated with electron gun 42 and positioned along the path of the electron beam is the set of deflection plates 43. For purposes of simplification a single pair of deflection plates is illustrated which will serve to deflect the electron beam in a single plane upon areas of storage screen 41, however, it will be apparent that an additional pair of deflection plates may be incorporated to provide deflections of the electron beam in a plane normal to that afforded by the plates illustrated. Thus, in response to signals applied to both pairs of deflection plates 43, the electron beam may be directed to any desired area on storage screen 41. An anode 47 is positioned between deflection plates 43 and storage screen 41 and serves both to accelerate the electron beam and to collect photoelectrons generated by elements of the storage screen 41 under conditions to be described in detail hereinafter. The particular configuration of anode 47 forms no part of the present invention and may be conveniently embodied as a conductive wall coating on the inside of tube envelope 40.

Storage screen 41 is positioned within the evacuated envelope 40 and in the path of the electron beam generated by electron gun 42. In the embodiment illustrated in Figure 6, screen 41 includes a layer of light sensitive material 11, a layer of electron sensitive material 12, and a screen 13 interposed between said laminae. Screen 13 has openings 16 therein which provide independent passageways for both electron streams emitted from surface 11 and light radiation produced from electron sensitive material 12. Storage screen 41 may also include a pair of transparent, conductive layers 48 and 49 which are positioned adjacent the layers 11 and 12, respectively, and serve to apply accelerating voltages thereacross. Storage screen 41 may also comprise a lamina of electron

sensitive material 50 arranged to directly receive electron images formed by the incident electron beam generated by gun 42, and transform said electron images into corresponding light images.

Means in the form of a voltage divider, referred to generally by reference numeral 52, is connected across a source of direct current voltage (not shown) and serves to provide suitable electric fields across lamina 11 and lamina 12, as well as maintaining the various electrodes, such as anode 47 and the elements of the electron gun 42, at their proper operating voltage levels. Voltage divider 52 includes dropping resistors 53 through 59 and with the source of voltage connected with proper polarity across the terminals indicated + and -, the voltage applied to conductive layer 49 by lead 61, under normal operating conditions, will be maintained at a positive potential with respect to the voltage applied to the conductive layer 48 by lead 62. Hence, the voltage applied across laminae 11 and 12 is the voltage drop appearing across resistor 54. Through connection by lead 63 to the junction of dropping resistors 55 and 56, suitable operating voltage is afforded anode 47, and under normal operating conditions anode 47 is maintained at a voltage level lower than either the voltage applied to lamina 11 or lamina 12. The elements of electron gun 52 are maintained at suitable operating potentials by being connected, as shown, across dropping resistors 58 and 59 of network 52.

A lead 64 is connected to control grid 45 of electron gun 42 and provides means for applying an intensity signal thereto which serves to trigger the electron beam generated by cathode 44 off and on. Leads 65 and 66 are connected to the deflection plates 43 and provide means for applying signals thereto whereby the electron beam generated by gun 42 is selectively directed over different areas of storage screen 41.

In operation, with a suitable energizing signal applied over lead 64 to control electrode 45, an electron beam is generated by cathode 44 and directed along the axis of envelope 40 toward the storage screen 41. In traveling toward screen 41, the electron beam is directed between deflection plates 43. By the application of signals to deflection plates 43 via leads 65 and 66, the electron beam may be selectively directed to different areas on screen 41, and by well known circuits the beam may be caused to be scanned, if desired, across the storage screen 41 in any desired raster.

Directed toward storage screen 41, the electron beam strikes the electron sensitive layer 50 with sufficient energy to cause it to generate a light image in accordance with the image produced thereon by the electron beam. As stated in the description relating to the storage device illustrated in Figure 2, lamina 50 may be produced from any of several fluorescent materials, such as phosphors of zinc, cadmium, or calcium. Where utilized in association with a relatively low energy electron beam, layer 50 serves to adapt the essential storage elements of the storage screen 41 to cathode ray tube applications, and it will become apparent to those skilled in the art that lamina 50 is not essential in cathode ray storage tubes wherein high energy cathode ray beams are utilized. In these latter applications, the high energy electron beam possesses sufficient energy to penetrate layer 48 and layer 11, traverse the openings 16 in screen 13, and strike the electron sensitive layer 12, whereupon a light image is generated in accordance with the incident electron image formed by the beam. However, for purposes of clarification, fluorescent lamina 50 is incorporated in the embodiment illustrated in Figure 6 and the light images formed thereon in response to bombardment by the electron beam pass through the transparent conductive layer 48 and strike light sensitive layer 11.

Conductive layer 48 is similar to conductive layer 24, described in connection with Figure 2, and is preferably a very thin, transparent coating of material, such as alu-

minum. As illustrated in Figure 6, the transparent metallic layer 48 is preferably arranged adjacent to and coextensive with light sensitive layer 11, and being connected through lead 62 to the voltage divider, network 52 serves to provide a substantially constant voltage over the entire area of surface 11.

Light sensitive surface 11, which serves to transform the light patterns produced by lamina 50 into corresponding electron images, may be a very thin layer, or film, produced from the "alkali-metals" which emit electrons in the presence of light. Lamina 11 is preferably a continuous layer and generates an integral electron image corresponding in detail to an electron image directed upon layer 50 by the cathode ray beam. Screen 13 is positioned adjacent the light sensitive layer 11 and serves primarily to subdivide the integral electron image produced on surface 11 into a plurality of independent elements which together form a composite image in accordance with the integral electron image. Screen 13 is structurally and functionally similar to the screen 13 shown in detail in Figure 4. As described, screen 13 is preferably a planar member, or lamina, of opaque material which is arranged to overlay and mask portions of the continuous light sensitive surface 11. Screen 13, with openings 16 therein, not only dissects the integral electron image formed on surface 11 into the independent elements of the composite image, but also serves to restrict the direction of travel of the resulting electron streams and consequently provides separate channels for each of the composite image elements directed toward the electron responsive lamina 12.

Under normal operating conditions, the electric fields applied between laminae 11 and 12 produce forces on the resulting electron streams which accelerate the bundle of streams through the channels formed by openings 16 toward electron responsive lamina 12. Lamina 12, which serves to convert electron bombardment into corresponding light patterns, is a thin film or coating functionally similar to layer 50 and may be similarly produced from any of the fluorescent materials mentioned hereinbefore. Hence, in response to bombardment by the electron streams, light elements are generated by lamina 12 which correspond to the electron elements forming the composite electron image, and the aggregate of the light elements produce an image corresponding to the composite electron image formed on the surface of lamina 11 adjacent screen 13. It, therefore, becomes apparent that each element of the light image produced on lamina 12 is energized by an electron stream derived from an area of surface 11 which lies beneath the opening in screen 13 associated with the particular incremental area of lamina 12 which produced the light element.

The light image formed upon lamina 12 by the individual light elements may be made visible through the transparent conductive layer 49 and a transparent end face 67 of envelope 40. As described hereinbefore, the image displayed on lamina 12 is sustained thereon through regenerative feedback of light to fluorescent lamina 11. A plurality of independent regenerative feedback paths between laminae 12 and 11 are provided by the openings in screen 13, which is interposed between the laminae. Light from each element of the image appearing on lamina 12 is channelled back to lamina 11 through the same opening in screen 13 in which the particular energizing electron stream travelled in producing the particular light element. Thus, elements forming the light pattern generated by lamina 12 in response to the electron streams forming the composite electron image, serve to re-energize the areas of surface 11 that originally produced the light element and in this manner the image described on lamina 50 by the electron beam produced by electron gun 42 is stored as a corresponding image visible through the end face 67 of the cathode ray tube.

The cathode ray display and storage device also includes circuit means 71 for selectively removing different

retained images from storage screen 41. Circuit means 71 is associated with the elements of the voltage divider 52, which serves to establish predetermined electric fields between the light sensitive lamina 11, electron sensitive lamina 12, and anode 47 for retaining the images produced by the cathode ray beam, and in addition to essential components described in connection with voltage divider network 52 includes an electron tube 72 having an anode 73, a cathode 74, and a control electrode 75. Anode 73 may be connected directly to terminal + of voltage divider 52 and the anode circuit is completed by connecting cathode 74 through a resistor 76 to the junction between dropping resistors 55 and 56 of divider 52. A grid return resistor 77 is provided, which is connected between an input terminal 78 and the junction of control grid 75 and a second input terminal 79. Thus, it may be seen that electron tube 72, with its associated components is actually in parallel with dropping resistor 55 and functions to selectively control the voltage applied to anode 47 over a voltage range sufficient to permit storage and image display or selective erasure of previously stored images in response to external signals.

Under operating conditions for writing, displaying, and storing an image, electron tube 72 is non-conductive and voltages are established by voltage divider 52 and applied to elements of the cathode ray tube which maintain anode 47 at a voltage level lower than either the voltage applied to lamina 11 or lamina 12. For descriptive purposes, it may be assumed that to establish the aforementioned normal operating conditions, the values of the various dropping resistors are so chosen that a potential of 10,000 volts appears at terminal +, a potential of 9,000 volts is established at the junction of resistors 53 and 54, and a potential of 8,000 volts is established at the junction of resistors 55 and 56. When it is desired to erase a previously stored image or a portion thereof a signal voltage is applied to control electrode 45 over lead 64 which serves to turn the electron beam on. By the application of suitable deflection signals applied to the deflection plates 43 over the leads 65 and 66, the electron beam is then directed to the area of the storage screen 41 to be erased. To actually initiate erasure of the image, an external selective erase signal is applied to electron tube 72 through input terminals 78 and 79. Electron tube 72 is thereby driven to become conductive whereupon dropping resistor 55 is essentially short circuited. Thus, the junction between resistors 55 and 56 is raised to a voltage level approximating the assumed 10,000 volts applied to terminal + of voltage divider network 52. Under these conditions and with accelerating anode 47 interconnected by lead 63 to the junction of resistors 55 and 56, the voltage applied to anode 47 is raised to approximately 10,000 volts and to a voltage level substantially higher than either the voltage applied to lamina 11 or lamina 12. Hence, electron emission from lamina 11 is now directed toward anode 47 as a result of the potential gradient appearing therebetween and electron emission is materially reduced in a direction toward lamina 12. This action reduces the electron flow from lamina 11 to lamina 12 below the critical point necessary to energize fluorescent lamina 12 and thereby removes this portion of the image. Anode 47 will remain at a positive voltage level with respect to both laminae 11 and 12 during the period the external selective erase signal is applied to the input terminals 78 and 79 of tube 72, and upon removal of this signal, anode 47 is restored to its normal voltage level and the device is returned to its normal operating conditions for writing, storing, and displaying an image.

Where a high energy electron beam is produced by the cathode ray tube, the fluorescent layer 50 may be eliminated and the device will function in generally the same manner. The ability of an electron beam to penetrate thin conductive layers, such as conductive layers 48 and 49, is well known and the incident electron beam gen-

erated by electron gun 42 and directed upon the storage screen penetrates light sensitive layer 11 as well as conductive layer 48, passes through the openings 16 of screen 13, and impinges upon electron sensitive lamina 12. Light produced by lamina 12 is directed back to lamina 11 and is localized by the openings in screen 13 to those areas of lamina 11 underlying the illuminated openings of the screen. Illumination of lamina 11 causes photoelectrons to be generated in proportion to the impinging light, and these photoelectrons are directed through the same opening in screen 13 to re-activate lamina 12. In this manner the electron image described by the incident electron beam is converted into a sustained image visible to an observer through transparent, conductive layer 49 and the transparent end face 67.

It will be apparent that the materials comprising either or both the laminae 11 and 12 may be selected to provide suitable electrical conductive characteristics and physically formed to allow the accelerating voltages developed by voltage divider 52 to be directly applied thereto over the leads 61 and 62. Hence, conductive layers 48 and 49 illustrated in Figure 6 also may be effectively eliminated.

A modification of the storage screen shown in Figure 6 is illustrated in Figure 7 and includes a continuous light sensitive lamina 11, a screen 81 having a plurality of openings therein, and a lamina of electron sensitive material 82 which is arranged within the openings of screen 81. An electric field is impressed across lamina 11 and the elements comprising lamina 82 by the leads 61 and 62 which are interconnected between the voltage divider 52 described in connection with Figure 6, and to conductive end face 83 and directly to the continuous light sensitive lamina 11, respectively. Lead 63 serves to interconnect the accelerating anode 47 with the junction of dropping resistors 55 and 56 and thereby supplies both the normal storage potentials and selective erase potentials thereto. Transparent conductive end face 83 is provided which may be fabricated from "electrically conductive glass" produced by methods referred to hereinbefore and is suitably sealed to envelope 84.

Screen 81 is generally physically and functionally similar to screen 13 described hereinbefore and illustrated in Figure 4 and is preferably a planar member of non-transparent material which has a plurality of small openings therein in the order of a few thousandths of an inch, such as openings 16. Fluorescent phosphor material 82, which serves to transform electron images into light, is arranged within the openings by, for example, a settling process. Thus, together the screen 81 and the fluorescent material 82 form a surface of isolated elements of electron sensitive material completely surrounded by the opaque areas of the screen. Screen 81 with the areas of fluorescent material therein is interposed between the electrically conductive glass surface 83 and the continuous light sensitive surface 11. The opaque portions of screen 81 serve to mask out portions of lamina 11 and prevent diffusion and scattering of light from the individual areas of fluorescent material.

Under operating conditions for writing and storing an image, voltage conditions developed by voltage divider 52 and applied over the leads 61, 62 and 63 establish the conductive surface 83 at a voltage applied to accelerating anode 47 at a voltage level lower than that applied to lamina 11. The electron beam produced by the electron gun of the cathode ray tube and directed toward the storage screen has sufficient energy to penetrate photocathode 11 and impinge directly upon the surface formed by the screen 81 and the isolated areas of fluorescent material 82 formed within the screen. The areas of fluorescent material 82 which are bombarded by the electron beam generate light patterns in accordance with the pattern described by the incident electron beam. However, with the configuration of the opaque screen 81 and fluorescent areas 82 as described, the electron image

written by the beam thereupon is transformed into a plurality of independent light elements, the sum of which correspond to the incident electron image. The light produced by the fluorescent material arranged in the openings of screen 81 serves to energize adjacent portions of the continuous light sensitive lamina 11. The resulting electron image thereby produced on lamina 11 serves to re-energize the corresponding adjacent elements of fluorescent material 82 interposed in the non-transparent screen 81. This regenerative action produces the desired retention of the image written by the electron beam generated by the cathode ray tube which may be readily viewed through the transparent end face 83.

It will be apparent that selective erasure of the entire image, or any portion thereof, may be accomplished in the manner described hereinbefore in connection with Figure 6. By the application of a selective erase signal to input terminals 78 and 79 of electron tube 72 associated with voltage divider 52, anode 47 is switched to a voltage level which is higher than either that applied to lamina 11 or conductive face 83 whereupon the image underlying the area of the screen to which the incident electron beam is directed is removed.

While certain preferred embodiments of the invention have been specifically disclosed, it is understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art, and the invention is to be given its broadest possible interpretation within the terms of the following claims:

What I claim is:

1. In an image storage device including a laminar electron sensitive material arranged to receive electron image emission and transform said image emission into corresponding light radiation patterns, a laminar light radiation sensitive material adapted to cause transformation of light radiation patterns into corresponding electron image emission, said image emission being directed toward said electron sensitive material, at least one of said laminae being a continuous surface, the improvement comprising a screen having at least one light transparent electron pervious portion and at least one non-conductive light impervious portion, said screen being interposed adjacent said laminae and arranged to overlay said continuous surface, said electron pervious portion being adapted to pass electron emission therethrough and said impervious portion being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said laminae.

2. In an image storage device including a lamina of electron sensitive material arranged to receive electron image emission and transform said image emission into corresponding light radiation patterns, a lamina of light radiation sensitive material adapted to cause transformation of light radiation patterns into corresponding electron image emission, said image emission being directed toward said electron sensitive material, at least one of said laminae being a continuous surface, the improvement comprising a screen having a plurality of light transparent electron pervious portions and a plurality of non-conductive light impervious portions, said screen being interposed adjacent said laminae and arranged to overlay said continuous surface, said electron pervious portions being adapted to pass electron emission therethrough and said impervious portions being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said laminae.

3. An evacuated image storage device comprising in combination a laminar electron sensitive material adapted to receive electron image emission and transform said image emission into corresponding light radiation patterns, a laminar photo emissive material capable of receiving said light radiation patterns and transforming said patterns into corresponding electron image emission, said image emission being directed toward said electron sensi-

5 tive material, at least one of said laminae being a continuous surface, and a screen having a light transparent electron pervious portion and a non-conductive light impervious portion, said screen being interposed adjacent said laminae and arranged to overlay said continuous surface, said pervious portion being adapted to pass said image emission, said impervious portion being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said laminae.

4. An evacuated image storage device comprising in combination a laminar electron sensitive material adapted to receive electron image emission and transform said image emission into corresponding light radiation patterns, a laminar photo emissive material capable of receiving said light radiation patterns and transforming said patterns into corresponding electron image emission, said image emission being directed toward said electron sensitive material, at least one of said laminae being a continuous surface, and a screen having a light transparent electron pervious portion and a non-conductive light impervious portion, said screen being interposed adjacent said laminae and arranged to overlay said continuous surface, said pervious portion being adapted to selectively accept and pass said image emission, said impervious portion being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said laminae, and means for establishing an electric field between said laminae, said means being adapted to cause acceleration of said image emission toward said electron sensitive material.

5. An evacuated image storage device comprising in combination a laminar electron sensitive material adapted to receive electron image emission and transform said image emission into corresponding light radiation patterns, a laminar photo emissive material capable of receiving said light radiation patterns and transforming said patterns into corresponding electron image emission, said image emission being directed toward said electron sensitive material, at least one of said laminae being a continuous surface, and a screen having a light transparent electron pervious portion and a non-conductive light impervious portion, said screen being interposed adjacent said laminae and arranged to overlay said continuous surface, said pervious portion being adapted to pass said image emission, said impervious portion being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said laminae, said electron sensitive material being disposed within at least a portion of said electron pervious portion, and means for establishing an electric field between said laminae of materials, said means being adapted to cause acceleration of said image emission toward said electron sensitive material.

6. In a cathode ray device including means for producing and directing a high energy electron beam emission along said device including an accelerating anode, a storage screen positioned within the device in the path of said beam emission, said storage screen including a first laminar electron sensitive material adapted to transform

said beam emission into corresponding light images, a laminar light sensitive material arranged to convert said light images into corresponding electron image emission, a second laminar electron sensitive material adapted to transform said image emission in corresponding light images, said image emission being directed toward said second electron sensitive material, at least one of said latter two laminae being a continuous surface, and a screen having light transparent electron pervious portions and non-conductive light impervious portions, said screen being interposed adjacent said latter two laminae and arranged to overlay said continuous surface, said pervious portion being adapted to pass said image emission, said impervious portion being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said latter two laminae, means for establishing predetermined electric fields between said light sensitive material, said second electron sensitive material and said accelerating anode to provide retention of said images, said means including a circuit arranged to change said retaining fields for selectively removing retained images from the screen.

7. In a cathode ray device including means for producing and directing a high energy electron beam emission along said device including an accelerating anode, a storage screen positioned within the device in the path of said beam emission, said storage screen including a laminar light sensitive material capable of converting light images into corresponding electron image emission, a laminar electron sensitive material adapted to selectively transform said electron beam emission and said image emission into corresponding said light images, said image emission being directed toward said electron sensitive material, at least one of said laminae being a continuous surface, and a screen having light transparent electron pervious portions and non-conductive light impervious portions, said screen being interposed adjacent said laminae and arranged to overlay said continuous surface, said pervious portion being adapted to selectively accept and pass said image emission, said electron sensitive material being disposed within at least a portion of said pervious portion, said impervious portion being adapted to isolate light radiation from said electron sensitive material, said screen being adapted to provide improved regeneration over limited areas of said laminae, means for establishing predetermined electric fields between said light sensitive material, said electron sensitive material and said accelerating anode to provide retention of said images, said means including a circuit arranged to change said retaining fields for selectively removing retained images from the screen.

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