United States Patent [19]

Webster

[11] **3,770,960**

[45] **Nov. 6, 1973**

[54] **X-RAY DISPLAY PANEL**

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[73] Assignee: **General Electric Company**, Schenectady, N.Y.

[22] Filed: **June 26, 1972**

[21] Appl. No.: **265,982**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 97,916, Dec. 14, 1970, abandoned.

[52] **U.S. Cl.** .....**250/460,** 313/108 R, 315/246

[51] **Int. Cl.**..... **G01t 1/16,** H01j 39/00

[58] **Field of Search**..... 250/80, 71 R, 83.3 R; 315/169 TV, 246; 313/89, 94, 101, 108 R, 108 A, 220, 210, 109.5

[56] **References Cited**

UNITED STATES PATENTS

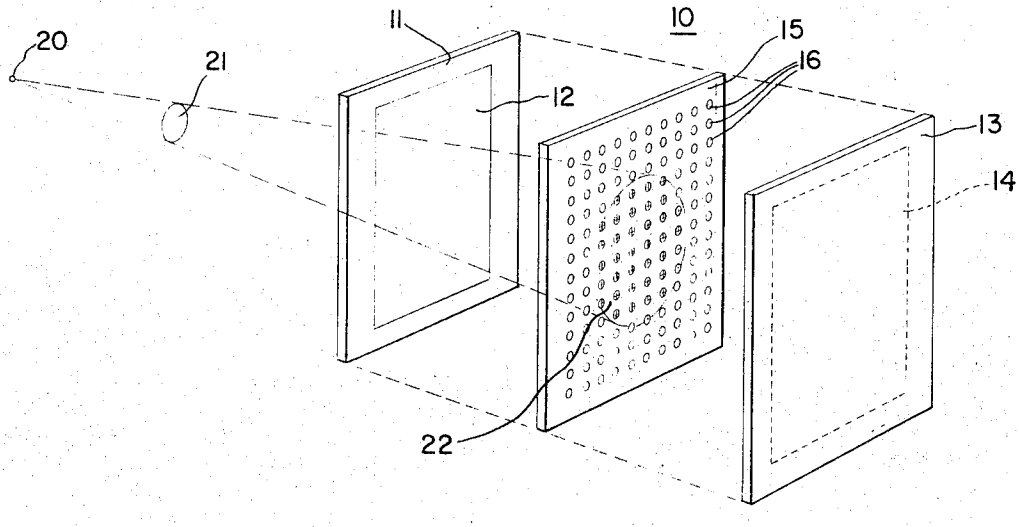
3,579,015	5/1971	Gregory	315/169 TV
3,334,269	8/1967	L'Heureux	313/108 R
2,500,929	3/1950	Chilowsky	315/169 TV
3,509,339	4/1970	Doehner	250/71.5 R
3,559,190	1/1971	Bitzer et al.	315/169 TV
3,584,216	6/1971	Tinney	250/80
3,603,837	9/1971	Turner	313/109.5
3,107,303	10/1963	Berkowitz	313/108 A
3,337,733	8/1967	Charpak et al.	250/71 R

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Assistant Examiner—Ronald J. Stern
Attorney—John F. Ahern et al.

[57] **ABSTRACT**

An improved x-ray display panel is disclosed wherein the x-rays forming the pattern to be displayed induce "ionizing events" over the surface of the panel. The photon producing discharges as a result of these events make up a visible image of the x-ray pattern.

17 Claims, 6 Drawing Figures



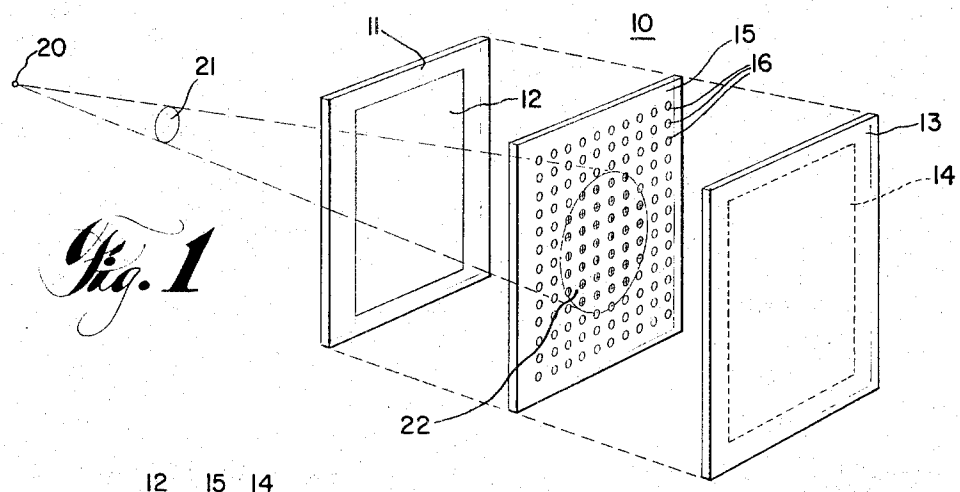


Fig. 1

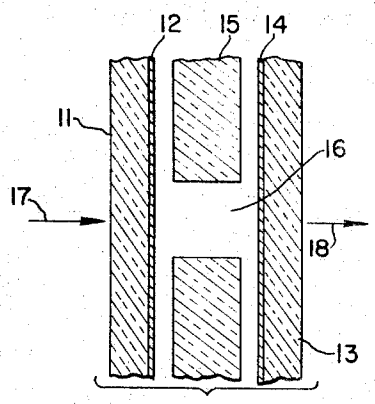


Fig. 2

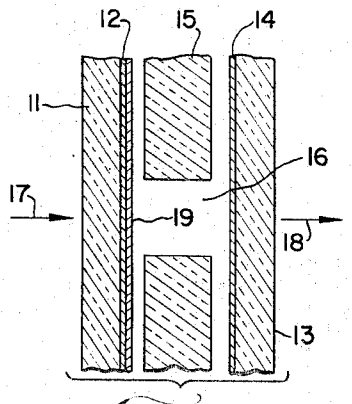


Fig. 3

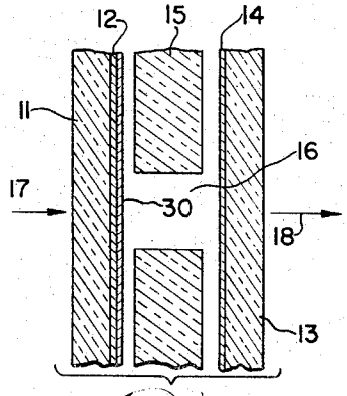


Fig. 4

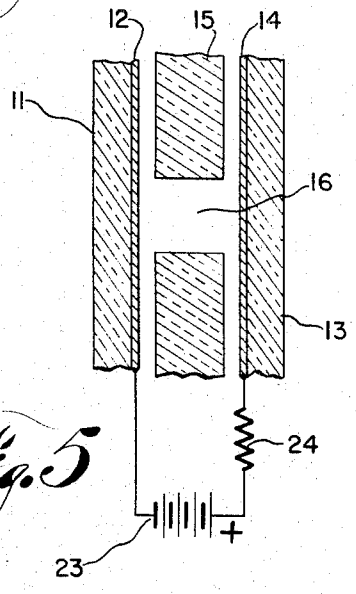


Fig. 5

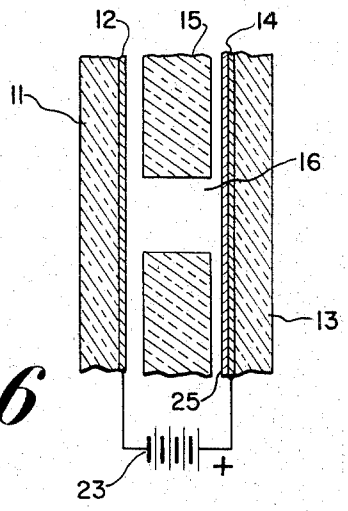


Fig. 6

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X-RAY DISPLAY PANEL

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of application Ser. No. 97,916, filed Dec. 14, 1970, now abandoned.

THE DISCLOSURE

This invention relates to display panels and particularly to a display panel for converting an x-ray image to visible light.

At present, x-ray images are viewed on fluoroscopes comprising a special phosphor screen sensitive to x-rays. These phosphors are relatively inefficient and the image produced thereby is rather dim.

Previous attempts to improve the operation of fluoroscopes generally fall into one or the other of two categories: either attempts are made at increasing the phosphor efficiency or an image intensifier is used. An image intensifier, for example, may comprise a phosphor layer plus a photoelectric surface upon which the image falls. Light from the phosphor liberates electrons from the photoelectric surface which are accelerated in an electric field and caused to strike a second phospher screen, yielding a much brighter image due to the increased energy of the electrons.

Each of these techniques has a number of drawbacks. Phosphor efficiency can only be increased a limited amount, i.e., energy conversion techniques are limited by the amount of input energy. The problem is not so much with the phosphor as with the radiation limits imposed. That is, the image could easily be made brighter by increasing the x-ray dosage. This, however, creates increased radiation hazards for the subject and for the operator. Thus, one is restricted to a low level radiation source and faced with the fact that energy conversion techniques will never achieve one hundred percent efficiency.

Image intensifiers, while beneficial in many respects, tend to be relatively expensive and restricted in size. The size restriction results from the electric field necessary to accelerate the electrons; the larger the field, the more difficult it is to generate. Thus, the area viewed with an image intensifier is smaller than that provided by a fluoroscope alone.

In or about 1966, a gaseous display and memory panel was developed at the University of Illinois for use as a graphic output device for digital computers. Te Illinois panel comprises a central glass plate having an array of holes arranged in regular rows and columns therein. The central glass plate is surrounded by first and second outer glass plates. The first outer glass plate contains a plurality of stripe electrodes in registration with the columns of holes in the second glass plate. The second outer glass plate contains a plurality of stripe electrodes in registration with the rows of holes in the central glass plate. By causing a computer output word to apply electrical potentials to one of the stripe electrdoes on the first outer glass plate and one of the stripe electrodes on the second outer glass plate, a gaseous discharge in one hole of the central glass plate is produced responsive to the computer output word. The gaseous discharge produces a point of light whose position in the array of holes in the central glass plate conveys a quantum of output information from the computer.

The genesis of this invention was the heretofore undisclosed realization that by making certain modifications in the operating parameters of the above described Illinois display panel, an improved x-ray display panel may be provided. Moreover, this invention includes the heretofore undisclosed realization that simplifying structural modifications to the prior art Illinois display panel can be advantageously made in an improved x-ray display panel. Specifically, if the electrodes of an Illinois panel are simultaneously, in parallel, connected across a source of electrical potential whose magnitude is not sufficient alone to cause breakdown across the perforated plate, such breakdown may be selectively stimulated by radiation thereby providing a radiation image display panel. Secondly, the structure can be modified by replacing the plurality of stripe electrodes on each outer plate of the Illinois panel with a single electrode of large area on each outer plate. This simplifies the fabrication of the required electrodes and eliminates the need for registration thereof with the perforations in the central plate.

In view of the foregoing, it is therefore an object of the present invention to provide a bright x-ray image screen.

It is a further object of the present invention to provide a bright x-ray image screen capable of being made in any desired size.

Another object of the present invention is to provide an image display wherein the input signal is used as a control signal rather than merely being converted to a visible form of energy.

A further object of the present invention is to provide an image display panel wherein the incident radiation provides an ionizing event within the panel thereby generating a visible electric discharge.

The foregoing objects and other advantages are achieved by the present invention wherein there is provided a display panel comprising parallel, spaced, electrically conducting radiation transmitting plates separated by a perforated plate. The spaced plates are connected to a source of high voltage. As x-rays strike the display panel, an x-ray emitted electron in the region of a hole in the perforated central plate causes a discharge through the hole resulting in a bright visible dot. THe region between the two outer plates is enclosed and filled with any suitable gas or mixture of gases; for example, neon or xenon.

A more complete understanding of the present invention may be obtained by considering the following detailed description in connection with the attached drawings in which:

FIG. 1 is an exploded view illustrating the overall arrangement of a display panel in accordance with the present invention.

FIG. 2 illustrates a side view, on a much larger scale, of a portion of the display panel.

FIG. 3 illustrates a modification of the present invention.

FIG. 4 illustrates another modification of the present invention.

FIG. 5 illustrates the operation of the present invention.

FIG. 6 illustrates an alternative mode of operation.

Referring to FIG. 1, there is illustrated the overall arrangement of display panel **10** in accordance with the present invention. Display panel **10** comprises a first outer radiation transmissive plate **11** having deposited

thereon a coating **12** thereby making a transparent electrode. A second outer radiation transmissive plate **13** has deposited thereon a conductive layer **14** making a second transparent electrode. Plates **11** and **13** may, for example, be glass, a polycarbonate plastic such as LEXAN (a trademark of General Electric Company) or other material having similar fluid-impervious radiation transmissive characteristics. Electrodes **12** and **14** may, for example, be films of a metal oxide such as tin oxide. Alternatively, a first electrode **12** which receives the x-ray energy from which an image is to be formed, may be a metallic electrode and may to advantage be a thin gold foil electrode; in either case electrode **14** is preferably a metal oxide film. Spaced between the two outer plates and separated therefrom by a small distance is a perforated plate **15** containing an array of holes **16.** The arrangement of holes **16** may be either random or in a pattern. It is preferred to have them in a pattern since the number of holes per unit area can be increased thereby. It is preferable to form the perforated plate of a dark-colored material in order to minimize reflection of room light and to maximize display contrast.

In operation, display panel **10** is either inserted into a suitable container or the volume contained within the outer plates sealed so that a suitable gas may be contained within the volume defined by the outer plates. For maximum display brightness, the gas is preferably either a mixture of a gas selected from the group consisting of nitrogen and hydrogen and a gas selected from the group consisting of helium, argon, and neon at a pressure of between one-half and 1 atmoshpere, or alternatively, pure xenon at a pressure of approximately one-half atmosphere. A source of potential, which may be either *a-c* or *d-c* is applied to electrode surfaces **12** and **14.** In a first example of a preferred embodiment of this invention, the gas employed was a nitrogen-neon mixture and a voltage of approximately 600 peak RF volts at various frequencies in the range 38 to 120 kilohertz was applied between electrodes **12** and **14.** The RF voltage was pulsed with cycles of 33 millisecond on-times and 1 to 3 millisecond off-times. During the off-times, any x-ray excited discharges in the perforations of the central plate are extinguished thereby providing for real-time dynamic x-ray display. In a second example, pure xenon gas was employed and a 300 volt d-c potential was applied between electrodes **12** and **14.** When x-rays, for example, from source **20** irradiate an object such as sphere **21,** a shadow will be cast upon the display panel as illustrated by circular pattern **22.** As the x-rays strike the panel, they act as an "ionizing event" and serve to initiate a discharge within holes **16** of the array of the central plate **15.** This is described in more detail with references to FIGS. **2–4.**

In accordance with an important feature of this invention, xenon is the preferred gas for filling the discharge cells comprising the perforations of the perforated central plate. Xenon is a heavy gas and accordingly absorbs x-rays well, emitting photoelectrons in response to the x-rays absorbed. The photoelectrons emitted are accelerated by the electric field maintained between electrodes **12** and **14** and typically collide with other xenon atoms which in turn emit secondary photoelectrons and so on in an avalanche effect. The providing of such avalanche effect is important in practicing this invention, because the more readily initiated avalanche in the heavy gas, xenon, increases the sensitivity of the triggering of the discharge cells by x-rays. This is important to the functioning of an x-ray display panel, whereas in contrast, it is not important to the functioning of a computer read-out panel such as the Illinois panel since, in the case of the read-out panel, triggering can be assured by simply increasing the electrical potential applied across the discharge cells.

FIG. **2** illustrates a section of display panel **10** specifically concerning the region around one of the holes **16** in array. Holes **16** may be obtained in any suitable fashion, however, in order to generate a large number of holes of relatively small size, resort may be made to the radiation damage etch technique developed by the General Electric Company. When an x-ray, symbolized by the arrow **17,** enters the display panel through outer plate **11,** an electron is emitted and drifts into the hole region **16.** The presence of electrons in the hole region induces an electric discharge between conductive layers **12** and **14.** This electric discharge then produces visible light symbolized by the arrow **18.** A viewer looking at the entire display panel would then see a pattern formed by the x-ray image in the form of a very large number of small dots of light not unlike a black and white image formed on a color television tube. All of the plates utilized in display panel **10** should be relatively opaque to ultraviolet radiation to prevent the accidental triggering of the display panel by room lights or the electrical discharge in adjacent holes within central plate **15.**

FIG. **3** illustrates a modification of the present invention wherein a thin layer **19** of a relatively heavy refractory metal is deposited over conductive layer **12** on the inside of objective plate **11,** that is, the plate facing the source of the x-ray image. This layer of heavy refractory metal **19,** which may for example be a very thin layer of lead, serves to increase the yield of photoelectrons and thus the sensitivity of the display panel **10** to an x-ray image. A similar result may also be obtained by making outer plate **11** of leaded glass, or by making electrode **12** itself of a metal foil. Gadolinium, lead, and gold have been found to be in that order, suitably efficient sources of x-ray stimulated photoelectrons. Accordingly, electrode **12** may advantageously be gadolinium foil or lead foil. Gadolinium is more efficient in producing x-ray stimulated photoelectrons, but lead is less expensive. The choice of the preferred material is therefore a design "trade-off."

FIG. **4** illustrates a further modification of the present invention wherein a layer of phosphor **30** is applied over conductive layer **12** on the objective plate. The phosphor layer **30** converts the x-rays to ultraviolet photons thereby increasing the sensitivity of display panel **10** to an x-ray image. The additional photons obtained by the modifications of FIGS. **3** and **4** act to increase the ionizing events within a hole **16** and serve to more readily cause an electric discharge thereby producing the visible image.

In FIG. **5** there is illustrated the over-all operation of an x-ray display panel in accordance with the present invention. When an ionizing event takes place within a hole-region **16,** discharge occurs between conductive plates **12** and **14.** The energy for this discharge is supplied by a power source symbolized by battery **23** which is coupled to conductive layers **12** and to conductive layer **14** by way of series resistance **24.** Series resistance **24** serves a current limiting function to pre-

vent "runaway" within the display panel. It has been found that, with this relatively simple configuration, a discharge within hole region **16** may tend to increase the voltage drop across series resistance **24** and inhibit discharges within other hole regions. The net effect is to tend to make the discharge occur sequentially rather than simultaneously.

Apparatus for overcoming the sequential discharge is illustrated in FIG. **6** wherein series resistance **24** has been replaced by what amounts to a plurality of parallel resistances connected one to each hole region. Specifically, the plurality of resistances preferably takes the form of a resistive coating overlying conductive plate **14.** Suitable materials for resistive layer **25** are ruthenium oxide, such as sold by Alloys Unlimited, Inc. under the trade name R17A resistive paste, or cobalt-silicon organo metallic solution, such as sold by Engelhart Industries. In the operation of FIG. **6,** an ionizing event will induce a discharge within hole region **16.** However, since each hole region is effectively connected to source **23** by its own resistor, the increase in voltage drop across each individual resistor is not coupled to the remaining resistors of the display panel. The result is then a simultaneous discharge of those regions in which an ionizing event has been described and illustrated, it will be apparent to those skilled in the art that many modifications can be made without departing from the spirit and scope of the present invention.

The invention claimed is:

1. In a radiation imaging system including a source of radiation for irradiating an object to be imaged and radiation detecting display means receiving radiation which has interacted with said object, an improved radiation detecting display panel comprising:

first and second radiation transmissive fluid impervious plates oriented generally parallel to one another and spaced apart;

a continuous unitary conductive coating applied over substantially the entire area of the interior surfaces of each of said plates to form first and second electrodes, at least one of said electrodes being light transmissive;

a plate having generally cylindrical voids therein extending therethrough for the entire thickness thereof placed between and generally parallel with said electrodes;

enclosure means for sealing in gas-containing relationship at least the region between said first and second plates and for containing a gas therein; and

a source of electrical potential coupled to said first and second electrodes and producing an electric field therebetween.

2. An improved radiation detecting display panel as set forth in claim **1** wherein one of said electrodes comprises a metal oxide film.

3. The display panel of claim **2** wherein said metal oxide film comprises tin oxide.

4. The display panel of claim **2** wherein the other of said electrodes comprises a metal foil electrode selected from the group consisting of gadolinium foil, lead foil, and gold foil.

5. An improved radiation detecting display panel as set forth in claim **1** wherein said gas includes a noble gas.

6. The panel of claim **5** wherein said gas is a mixture of a gas selected from the group consisting of hydrogen and nitrogen with a gas selected from the group consisting of helium, neon, and argon.

7. The panel of claim **5** wherein said gas is xenon.

8. An improved radiation detecting display panel is set forth in claim **1** wherein said voids form a geometric pattern of voids in said plate having voids.

9. An improved radiation detecting display panel as set forth in claim **1** wherein said voids form a random pattern of voids in said plate having voids.

10. An improved radiation detecting display panel as set forth in claim **1** wherein said first and second plates are relatively opaque to ultraviolet radiation and transparent to visible radiation.

11. An improved radiation detecting display panel as set forth in claim **1** wherein said source of electrical potential comprises a direct current source.

12. An improved radiation detecting display panel as set forth in claim **1** wherein said source of electrical potential comprises an alternating current source.

13. The panel of claim **12** wherein said alternating current source is a pulsed RF source having a carrier frequency in the range 38 kHz to 120 kHz.

14. A display panel as set forth in claim **1** wherein one of said first and second plates further includes a layer of heavy metal.

15. A display panel as set forth in claim **1** wherein one of said first and second plates further includes a layer of ultraviolet photon producing phosphor.

16. A display panel as set forth in claim **1** wherein one of said first and second plates comprises leaded glass.

17. A display panel as set forth in claim **1** wherein one of said first and second plates has a resistive layer overlying said conductive coating.

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