United States Patent [19]

Weber

[11] **3,800,296**

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[54] **OPTICAL WRITE-IN METHOD AND APPARATUS FOR A PLASMA DISPLAY PANEL**

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[73] Assignee: **University of Illinois Foundation,** Urbana, Ill.

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[21] Appl. No.: **247,837**

[52] **U.S. Cl.**..... **340/173 PL,** 178/7.3 D, 315/169 R, 250/213 A, 340/166 EL

[51] **Int. Cl.** **G11c 11/28,** H01j 15/00

[58] **Field of Search** ..... 340/173 R, 173 PL; 178/6.6, 6.7, 7.3 D; 179/110

[56] **References Cited**

UNITED STATES PATENTS

3,723,977	3/1973	Schaufele	340/173 PL
3,293,441	12/1966	Kazan	340/173 PL
3,559,190	1/1971	Bitzer	340/173 R
3,573,542	4/1971	Mayer	340/173 R
3,579,015	5/1971	Gregory	340/173 PL
3,651,509	3/1972	Ngo	340/173 PL

Primary Examiner—Terrell W. Fears

Attorney, Agent, or Firm—Merriam, Marshall, Shapiro & Klose

[57] **ABSTRACT**

A method and apparatus for changing the states of gaseous discharge cells in a plasma panel including applying a light flash to the cells simultaneously during a discharge of the cells. Transferring an image to the plasma panel by applying a light flash corresponding to the image to the gaseous discharge cells simultaneously during a repetitive sustaining discharge of the cells.

16 Claims, 4 Drawing Figures

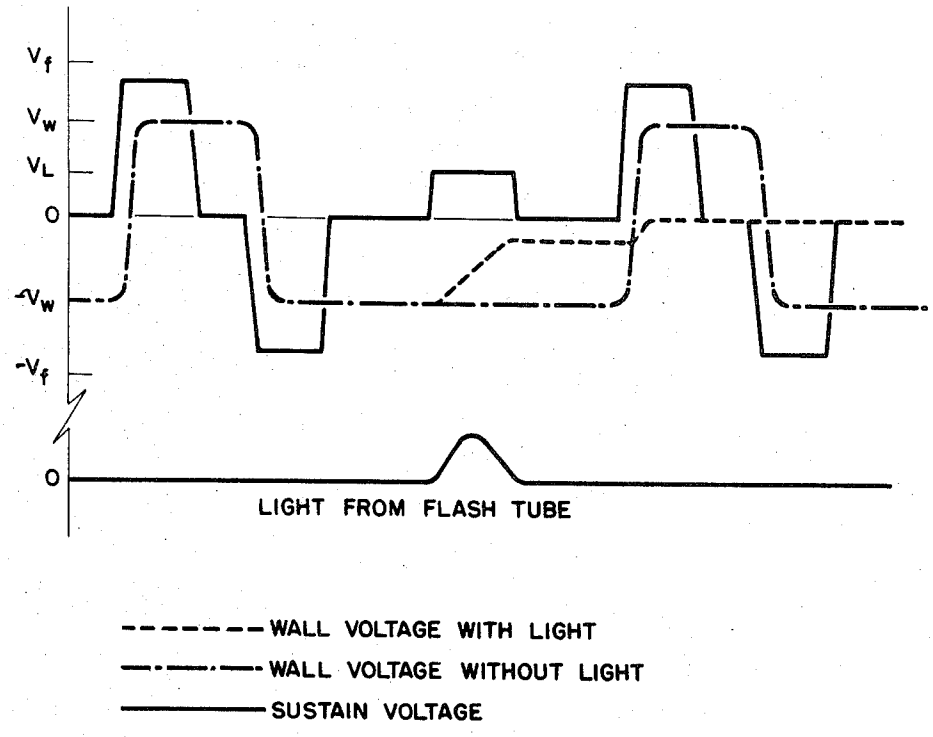


FIG. 1

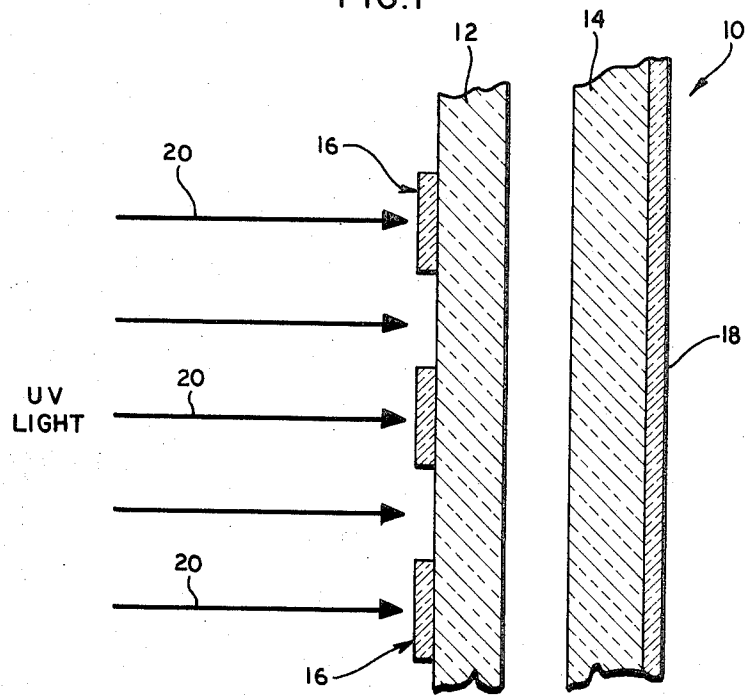
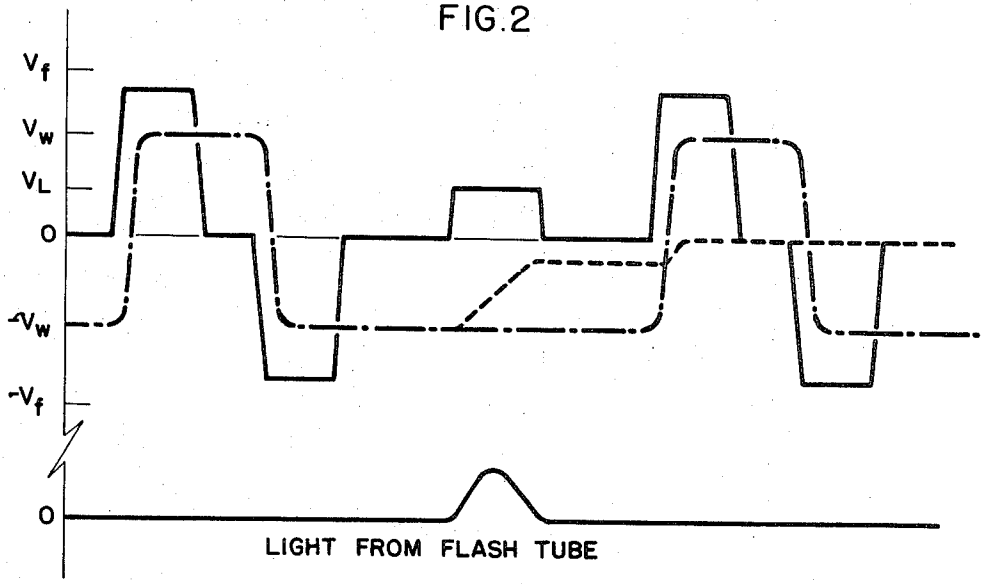


FIG. 2



- - - - - - WALL VOLTAGE WITH LIGHT

—·—·— WALL VOLTAGE WITHOUT LIGHT

——— SUSTAIN VOLTAGE

FIG. 3

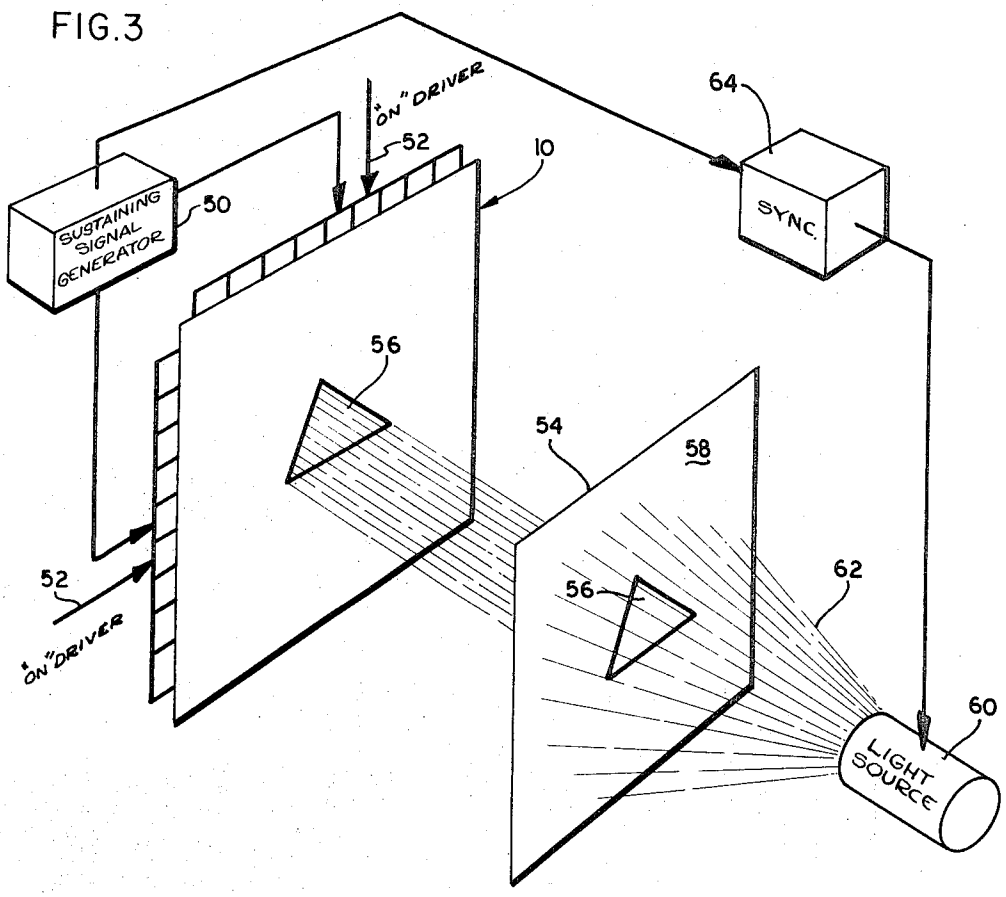
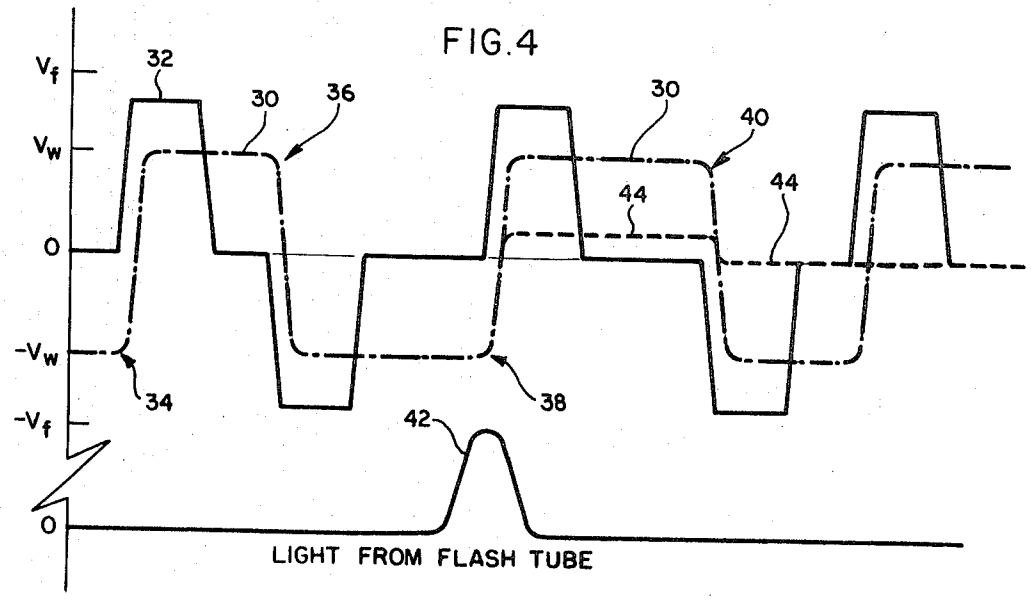


FIG. 4



WALL VOLTAGE WITH LIGHT

WALL VOLTAGE WITHOUT LIGHT

SUSTAIN VOLTAGE

OPTICAL WRITE-IN METHOD AND APPARATUS FOR A PLASMA DISPLAY PANEL

This invention relates to plasma panel systems, and in particular to an improved method and apparatus for optically writing information into a plasma display panel. The invention herein described was made in the course of or under a contract with the Department of the U.S. Army.

The plasma panel is a two dimensional array of light emitting gas discharge elements that exhibits inherent memory. This type of plasma panel has been previously described in U.S. Pat. No. 3,559,190, issued Jan. 26, 1971, on an application of D. L. Bitzer, H. G. Slottow and R. H. Willson, entitled "Gaseous Display And Memory Apparatus," U.S. Ser. No. 613,693, filed Dec. 22, 1966, assigned to the same assignee as here. The plasma panel described in the aforementioned patent comprises a plurality of discharge cells having associated electrodes for discharging the gaseous medium within selected cells and forming corresponding cell wall charges, the presence or absence of wall charges conveying the desired display information. The plasma panel is normally termed a "plasma display panel" although it is also useful as an information storage or memory panel, with or without its display capability.

The operation of selectively addressing the plasma display panel to write information, and the sustaining operation is well known in the art. Reference may be made to the aforementioned U.S. Pat. No. 3,559,190 for a specific description thereof. A plasma display panel includes as is known in the art a series of corresponding X and Y electrodes such that the intersection of any two electrodes can be selectively addressed by means of suitable addressing means coupled to the associated corresponding electrodes. The application of suitable addressing or drive signals forms a discharge of the gaseous medium within the respective cells thereby forming a corresponding cell wall charge. The formed wall charge opposes the drive signal thereby rapidly extinguishing the discharge. The presence or absence of wall charges convey the desired information. The information can be maintained in the panel by application of an alternating sustaining signal which by itself is not sufficient to discharge a cell without a wall charge, but is sufficient to discharge a cell having a wall charge on alternating half cycles of the sustaining signal.

In the aforementioned patent, U.S. Pat. No. 3,559,190, there is also described a technique for utilizing a light beam directed through a document to project an image onto a plasma display panel. As there described, if particles are produced in the cell by photoelectric emission, a wall charge within the light impinged cell is formed so that the combination of the wall voltage, due to the charge, and the applied sustaining signal is sufficient to discharge those cells being impinged with light. The projected image is thereafter retained on the plasma display panel by means of the sustaining signal source and the light beam can thereafter be removed.

A detailed description of the known prior art is set forth in a publication of the Coordinated Science Laboratory, University of Illinois, Urbana, Illinois, entitled "Optical Write-In Techniques For The Plasma Display Panel," Report R-510, May 1971. In addition, reference may be made to an article entitled "Optical Write-In For The Plasma Display Panel," L.F. Weber, published in the IEEE Transactions On Electron Devices, September 1971. Such prior art may be briefly summarized as follows.

A typical plasma display cell in the one state has on the order of 10^7 electrons on the wall, and it has been calculated that on the order of 10^{10} photons may be needed to change the state of a single cell. Since this is a sizeable number, effort has been directed toward reducing the amount of light needed.

The obvious way to do this is to change the solid cell material to one with a higher quantum efficiency. This may be done by coating the glass wall with a good photocathode material, such as Cs. This, however, involves a search for materials that will not adversely affect the cell properties and that will not decompose in the environment of an intense gas discharge. Because of the difficulties involved in such a search, effort has been directed toward decreasing the amount of light needed to change the state without changing the solid panel materials. This left as parameters the gas mixture, the sustain waveform, and the time of the light flash relative to the sustain waveform.

A simple way to decrease the amount of light needed is to apply a voltage across the panel at the time of the projected light flash, so that a large electric field will be across the gas volume. The photoelectrons from the cathode will start electron avalanches. The avalanches will cause a large current to flow that will cause a larger wall voltage perturbation. The theory of this process is called avalanche amplification. Gains greater than 100 are obtainable with this technique. The type of gas mixture used has not been found to affect the avalanche amplification very much.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, there is provided a method and apparatus for significantly increasing the reliability of optically writing in the information desired into a plasma panel. It has been found that the intensity of projected light needed to change the state of cells can be reduced (even below that attainable with avalanche amplification) by synchronizing the projected light image on the plasma panel with the discharge of the plasma display panel cells. At the present time, it appears that a gas mixture of neon plus 1–2 percent nitrogen is effective in obtaining the advantages of this invention, particularly when utilized with sustaining voltage pulses having a 10–90 percent rise time of at least 0.6 microseconds. As noted in the aformentioned article, information of 1,600 bits from a transparent projection film was transferred utilizing the optical write-in method of this invention to a plasma panel in parallel in less than 10 microseconds. In fact, the initial image was made by exposing the transparent projection film to a plasma display panel exhibiting the information. Thus, the information contained in the display panel was optically stored on the transparent projection film and after the required development time of 15 seconds, the film was used to transfer the information back into the plasma panel as desired.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view illustrating a portion of a plasma display panel and the controlled application of light for writing information into the panel;

FIG. 2 is a schematic diagram illustrating various waveforms associated with an optical write in technique using avalanche amplification;

FIG. 3 illustrates in schematic block diagram form apparatus which may be used for optically writing in information in accordance with the present invention; and

FIG. 4 schematically illustrates various waveforms useful in describing the present invention.

DETAILED DESCRIPTION

FIG. 1 illustrates a partial sectional view of a plasma panel **10** constructed, for example, as indicated in the aforementioned U.S. Pat. No. 3,559,190 and including a pair of insulating members **12, 14** with a gaseous medium therebetween. A pair of transversely disposed conductive electrode grids **16** and **18** are insulatably mounted on opposing sides of the panel **10** as shown in FIG. **1.** The panel is subjected to a projecting beam of ultraviolet light as illustrated by the light rays **20** in FIG. **1.**

FIG. 2 illustrates the aforementioned method of using avalanche amplification to decrease the amount of light needed to switch a cell from the "on" state to the "off" state.

Assuming photoemission to be the primary cause of the photocurrent, the photocurrent can be amplified by placing a field across the gas volume so that the photoelectrons will initiate electron avalanches in the gas. This method of amplification has long been used in phototubes to increase sensitivity. The sustain voltage waveform and flash timing for switching cells to the off state, by using avalanche amplification, is shown in FIG. **2,** it being noted that a voltage V_L is placed across the panel at the time of the light flash. In fact, the sustain waveforms allow a field to be across the gas volume at the time of the light flash, so that avalanche amplification will certainly occur. However, this amplification is increased with the added pulse V_L of FIG. **2.** If V_L is too large, a gas discharge will occur that will appreciably alter the wall voltage independently of the applied light. This fact sets the limit to the amplification obtainable from this technique. The limit of the voltage across the gas volume V is set forth in the aforementioned publications.

For certain conditions, the flash of light during a gas discharge will cause the discharge to decrease in intensity, thereby transferring less wall charge than an ordinary discharge. Flashing the light during a gas discharge offers a technique for perturbing the wall voltage and thus changing the state of plasma cells. FIG. **4** shows a method for switching cells from the on state to the off state. This technique seems to require considerably less light than any techniques discussed so far.

As shown in FIG. **4,** the wall voltage waveform **30** of a cell having wall charges (in the on state) is repetitively discharged by the sustaining signal waveform **32** as noted at points **34, 36, 38, 40.** However, if a light pulse **42** is impinged on the cell during a gas discharge, as for example, a point **38,** the cell wall voltage does not follow waveform **30,** but instead the discharge is diminished and the modified cell wall voltage waveform **44** results. Thus, instead of the next gas discharge occurring at **40,** the flashing of light pulse **42** during discharge **38** has perturbed the wall voltage to waveform **44** so that on succeeding cycles of the sustaining signal the wall voltage will converge to the zero state as shown in FIG. **4,** or to any other desired state. The cell has therefore been switched from the on state to the off state by flashing the light pulse **42** during a gas discharge and producing a perturbation in the wall voltage.

The physics of this effect is not so well understood as that of avalanche amplification. Thus, the general characteristics will be presented with some speculative explanations. The discharge effect seems to have the same basic photoresponse characteristics as the photoemission processes discussed above. A quartz-glass panel experiment was performed with the light pulse being supplied by a flash tube. The discharge effect perturbed the wall voltage considerably more when the glass was the cathode than when the quartz was the cathode. The wall voltage perturbation of the discharge effect is greatly weakened when a 6-mil sheet of glass is placed between the quartz-glass panel and the flash tube. On the basis of experimentation one can conclude that the decrease in the intensity of the discharge is basically due to photoemission.

Intuitively, one would expect the photoelectrons emitted from the cathode to increase the intensity of the discharge. Inspection of the early stages of the discharge illuminated with light shows this to be the case. The discharge which is illuminated with light is more intense in its early stages than the unlighted discharge. However, as the unlighted discharge matures, it becomes more intense, so that its total time integrated current is considerably greater than the integrated current for the discharge with light.

In all gas mixtures studied, the light always caused greater current to flow for the early part of the discharge. The effects of light on the total integrated current or charge transfer for various gas mixtures is not so consistent. In some mixtures, the light simply advances the discharge without appreciably changing the charge transfer. In others the charge transfer is greatly altered. It was also found that the shape of the sustain waveform can greatly affect the amount of charge transfer in a lighted discharge.

To understand these effects, a detailed analysis of the gas discharge dynamics is needed. It appears, however, that the current caused by the light in the early part of the discharge is altering the wall voltage significantly. When the discharge normally matures, the voltage across the gas is reduced, so that an intense discharge cannot occur, thus reducing the charge transfer.

A detailed analysis of behavior of the discharge effect for various gas mixtures has not been made. However, initial data seems to indicate that with the panel under experimentation the discharge effect is not effective in changing the state of cells for gas mixtures of Ne plus less than 0.1 percent impurity gas, such as N_2 or Ar. Reference may be made to the aforementioned publications for a description of the experimental panel and conditions. In these mixtures, the panel will operate in the normal distable pulsed discharge mode; the light flash simply advances these discharges with little effect on charge transfer.

The gas mixture that seems to work best is Ne plus 1–2 percent N_2. The aforementioned experimentation was conducted with a mixture of 297 torr Ne plus 3 torr N_2.

The rectangular sustain voltage pulses (waveform **32**) used in these experiments have a 10 to 90 percent risetime of 0.6 μs. The gas discharge for mixtures of Ne

plus 1 percent N_2 occurs while the sustain pulse is still rising. Thus the risetime is an important parameter in determining the nature of a discharge. In general, if the risetime of the sustain pulse is increased, the halfwidth of the discharge current will increase, and the peak intensity will decrease. There seems to be an optimum risetime for maximizing the wall voltage perturbation of the discharge effect. By placing a capacitor in parallel with the panel, the risetime could be increased by loading the sustain generator with increased capacitance. It appears that with the sustaining signal risetime at 0.6 μs the effect is not optimized. It takes less light to control the state of the cells as the risetime is increased to about 1 μs. Further increase in the capacitance and risetime, however, seems to degrade the performance of the ordinary discharges, making them weak and difficult to sustain.

In neon mixtures with less than 0.1 percent impurity gas, varying the risetime does not seem to improve wall voltage perturbation of the discharge effect. In these gas mixtures, the discharge generally is of longer duration and smaller peak intensity. Also, the discharge does not grow as fast, so that it generally occurs after the sustain pulse has risen to its constant peak value. Thus, one may not expect the risetime to be of much importance in the characteristics of this type of discharge.

The effects of the risetime on the 1 percent N_2 mixtures may be explained as follows. The amount of wall voltage perturbation should depend on the number of photoelectrons emitted during the early part of the gas discharge. Since the longer risetime sustain pulse causes a longer lasting discharge, the time that photoelectrons will be effective in altering the discharge may be longer than for the faster risetime case. Thus a less intense light is needed to accomplish the same wall voltage perturbation. A further increase in risetime makes the voltage (at the time of the discharge) too low to sustain a stable series of discharges, and thus the properties of the discharge are degraded.

These experimental results and explanations with regard to the risetime and the gas mixture are tentative in that the results may depend on a particular aspect of sustain pulse shape used in these experiments which changes when the risetime changes. These results are presented only to indicate basic effects that deserve further study.

Referring now to FIG. **3**, there is illustrated typical apparatus which can be utilized to rapidly optically write-in information in parallel to the plasma panel. As shown in FIG. **3**, the schematic diagram of the plasma panel **10** incorporates the usual crossing grid of opposing electrodes which are respectively coupled to a sustaining signal generator **50**. The sustaining generator **50** presents a voltage waveform **32** across each plasma cell so as to repetitively discharge those cells in the on state, and leaving off those cells in the off state. Through connecting lines **42**, each of the plasma cells can be selectively driven to discharge the associated gas to put them into a desired state.

A transparent film **54** includes a transparent image **56** surrounded by opaque areas **58**. A transparent projection film, Polaroid 146–L, is one example of a transparency which can be used. A light source **60** emits electromagnetic radiation which is effective in causing photoelectric emission from the plasma panel cathode. The light source **60** emits rays **62** which are directed through the document **54** to project the image **56** on plasma panel **10**. One example of a light source which has been used is an E.G. and G.FX6–AU xenon flash tube which emits a relatively continuous spectrum from 2,300 A. on up through the infrared. The tube was connected to a 5 microfarad capacitor charged to 800 volts, giving a flash energy of 1.6 joules. In this configuration, the light flash had a halfwidth of 3 microseconds and a 10 percent to ten percent time of five microseconds. The light source **60** is triggered from the logic forming a part of the sustaining signal generator **50** so that the light flash from light source **60** will occur at the desired discharge time relative to the sustain voltage sequence as shown in FIG. **4**. This synchronization operation between the sustaining signal and the light source turn on is represented by synchronizer **64**.

The sustaining signal generator **50** used in the aforementioned experiments provides positive and negative rectangular voltage pulses (see waveforms **32**, FIG. **4**) having a typical width of 10 microseconds and a repetition frequency of 50 kHz.

As an operating example, all of the cells on the plasma panel **10** can be put into their on state by suitable driving signals applied on lines **52**. It is understood, of course, that the signals on line **52** can thereafter be removed and the cells maintained in their on state by being repetitively discharged by the sustaining signals from generator **50**. The image **56** on document **54** can now be transferred to the panel by synchronizing the application of a light flash from light source **60** with a discharge of the plasma cells. As shown in FIGS. **3** and **4**, this can most readily be accomplished by triggering the light source from the sustain voltage generator logic so that the flash would occur at the desired plasma cell discharge time relative to the sustain voltage sequence. Thus, those cells receiving light from the flash tube will be changed from the on to the off state, whereas those cells corresponding to the opaque portion of document **54** would remain in the on state.

In some systems in which two or more on states are used, the light flashes can be applied during respective discharges to switch the cells between states. In such systems this optical write in technique can be used to selectively change selected cells from any particular stable state to any other stable state.

For example, in display applications having two on states (A and B), and an off state (C), wherein separate display images are associated with the respective A and B states, the present invention can be used to place the A state cells in the C state thereby erasing the A image from the plasma panel and leaving the B image.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom as modifications will be obvious to those skilled in the art.

What is claimed is:

1. In a plasma panel having gaseous discharge cells, each of said cells having a respective wall voltage and a gas volume, a method for changing the state of said cells comprising impinging a light flash on said cells causing photoemission into the respective gas volume of said cells thereby perturbing said respective wall voltage, while simultaneously discharging said cells.

2. The method as claimed in claim **1**, wherein said cells in said plasma panel are maintained in an on state by repetitively discharging said cells, the method fur-

ther including changing the state of said cells by impinging said light flash during one of said repetitive discharges.

3. A method of transferring an image to a plasma panel having a plurality of gaseous discharge cells, each of said cells having a respective wall voltage and gas volume, said method comprising:

providing a discharge signal to discharge said cells;

providing a light flash corresponding to said image;

impinging said light flash on at least a portion of said plasma panel causing photoemission into the respective gas volume of said cells thereby perturbing said respective wall voltage; and

simultaneously applying said discharge signal to said panel during said light flash for changing the state of cells on said panel being impinged with said light flash, thereby transferring said image to said panel.

4. The method of transferring an image into a plasma panel as claimed in claim 3, wherein said plurality of discharge cells are initially in an off state prior to said transfer, and preventing said discharge cells in the light flash impinged portion of said panel from being changed to the on state.

5. The method as claimed in claim 3, wherein said image contains at least two contrasting areas and wherein said light flash impinged on said plasma panel corresponds to one of said contrasting areas.

6. A method of transferring an image to a plasma panel having a plurality of gaseous discharge cells, each of said cells having a respective wall voltage and gas volume, said method comprising:

driving all of said discharge cells on said plasma panel to an on state;

repetitively discharging said cells for maintaining said cells in said on state;

providing a light flash corresponding to said image; and

simultaneously impinging said light flash on at least a portion of said plasma panel during one of said repetitive discharges causing photoemission into the respective gas volume of said cells thereby perturbing said respective wall voltage for changing the state of cells in the light impinged portion of said plasma panel without changing the state of cells in the non-light impinged portion of said panel.

7. The method as claimed in claim 6, wherein said cells in the light impinged portion of said plasma panel are changed from said on state to an off state for transferring said image on said panel.

8. The method as claimed in claim 6, wherein said image contains at least two contrasting areas and wherein said impinging light flash on said plasma panel corresponds to one of said contrasting areas.

9. The method as claimed in claim 6, including applying a sustaining signal to said plasma panel for repetitively discharging said cells for maintaining said cells in the on state.

10. In a plasma panel system including a plasma panel having a plurality of gaseous discharge cells, each of said cells having a respective wall voltage and gas volume, and respective groups of cells being respectively maintained in at least two different on states by associated sustaining signals, a method for transferring an image into said plasma panel, said method comprising:

providing a light flash corresponding to said image; and

simultaneously impinging said light flash on said plasma panel during the repetitive discharge of one of said respective groups of cells causing photoemission into the respective gas volume of said cells thereby perturbing said respective wall voltage for changing the state of said cells on said light impinged portion of said panel, without changing the state of cells on the non-light impinged portion of said panel.

11. In a plasma panel having gaseous discharge cells, each of said cells having a respective wall voltage and a gas volume, apparatus for changing the state of selected cells comprising means for discharging said cells, and means for impinging a light flash on said cells simultaneously during the discharge thereof, said last mentioned means including means for causing photoemission into the respective gas volume of said cells for perturbing said respective wall voltage.

12. The apparatus of claim 11, wherein said cells in said plasma panel are maintained in an on state by means for repetitively discharging said cells, the apparatus further including means for changing the state of said cells by impinging said light flash during one of said repetitive discharges.

13. Apparatus for transferring an image to a plasma panel having a plurality of gaseous discharge cells, each of said cells having a respective wall voltage and gas volume, said apparatus comprising:

means for providing a discharge signal to discharge said cells;

means for providing a light flash corresponding to said image;

means for impinging said light flash on at least a portion of said plasma panel;

said last mentioned means including means for causing photoemission into the respective gas volume of said cells for perturbing said respective wall voltage; and

means for simultaneously applying said discharge signal to said panel during said light flash for changing the state of cells on said panel being impinged with said light flash, thereby transferring said image to said panel.

14. The apparatus of claim 13, wherein said plurality of discharge cells are intiailly in an off state prior to said transfer of said image into said panel, and including means for preventing said discharge cells in the light flash impinged portion of said panel from being changed to the on state.

15. Apparatus for transferring an image to a plasma panel having a plurality of gaseous discharge cells, each of said cells having a respective wall voltage and gas volume, said apparatus comprising:

means for driving all of said discharge cells on said plasma panel to an on state;

means for repetitively discharging said cells for maintaining said cells in said on state;

means for providing a light flash corresponding to said image; and

means for simultaneously impinging said light flash on at least a portion of said plasma panel during one of said repetitive discharges for changing the state of cells in the light impinged portion of said

plasma panel without changing the state of cells in the non-light impinged portion of said panel;

said last mentioned means including means for causing photoemission into the respective gas volume of said cells for perturbing said respective wall voltage.

16. In a plasma panel system including a plasma panel having a plurality of gaseous discharge cells, each of said cells having a respective wall voltage and gas volume, and respective groups of cells being respectively maintained in at least two different on states by associated sustaining signals, apparatus for transferring an image into said plasma panel, said apparatus comprising:

means for providing a light flash corresponding to said image; and

means for simultaneously impinging said light flash on said plasma panel during the repetitive discharge of one of said respective groups of cells for changing the state of said cells on said light impinged portion of said panel, without changing the state of cells on the non-light impinged portion of said panel;

said last mentioned means including means for causing photoemission into the respective gas volume of said cells for perturbing said respective wall voltage.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,800,296 Dated March 26, 1974

Inventor(s) Larry Weber

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 4, "one" should be --on--.

Column 3, line 60, "a" should be --at--.

Column 7, line 53, "on" should be --to--.

Column 8, line 49, "intiailly" should be --initially--.

Signed and sealed this 31st day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents