United States Patent

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[73] Assignee **The United States of America as represented by the Secretary of the Army**

[54] **FLAT DISPLAY TUBE WITH ADDRESSABLE CATHODE**
10 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **313/103,** 313/67, 313/109
[51] **Int. Cl.** **H01j 43/06,** H01i 43/08
[50] **Field of Search** 313/67, 68, 103, 104, 105, 109

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ABSTRACT: A flat panel display device having a striped address system wherein an electron beam from a selected one of several elemental emitting strips of either a field emission type cathode, a photoemissive cathode or a thermionically emissive cathode is caused to impinge upon a corresponding region of a phosphor screen to produce visible emission from said region, said device including means for multiplying the number of electrons emitted from the cathode so as to permit use of a cathode of smaller current density.

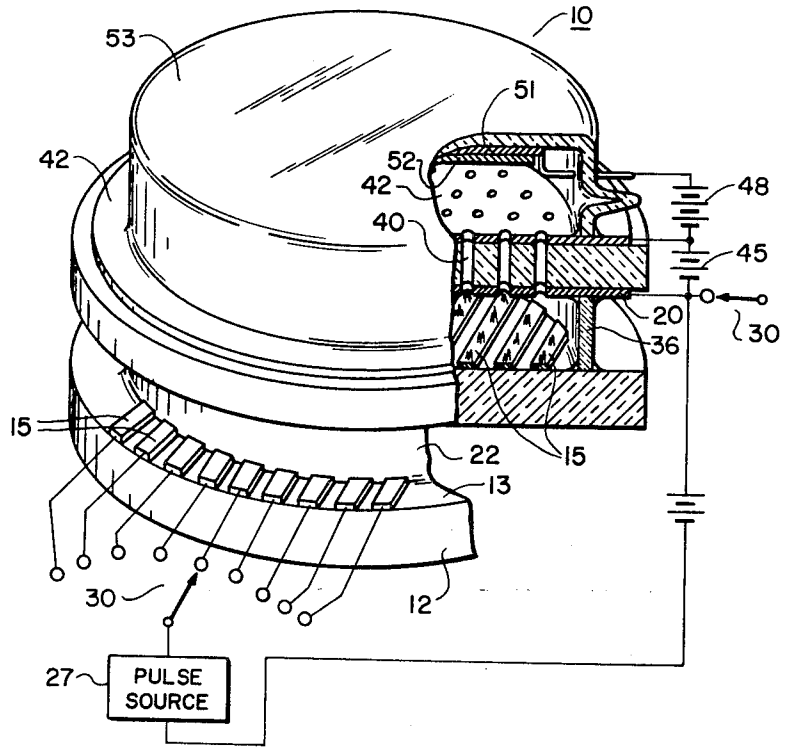


FIG. 1

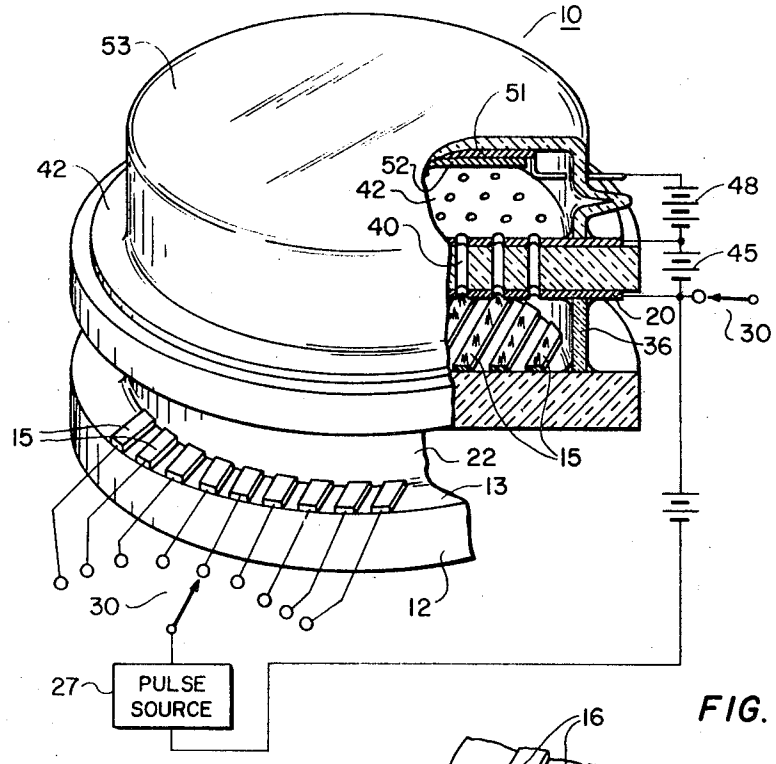


FIG. 2

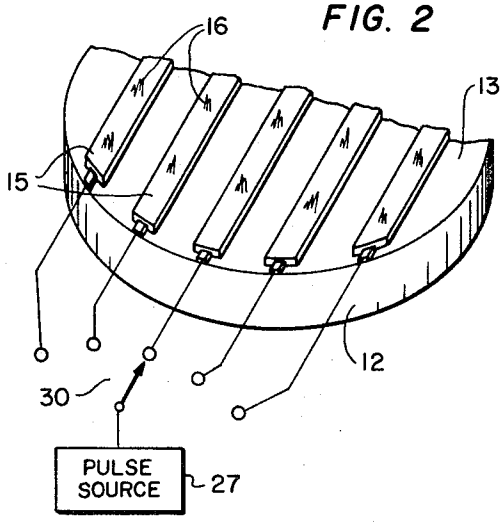
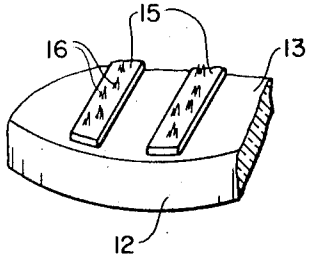


FIG. 3



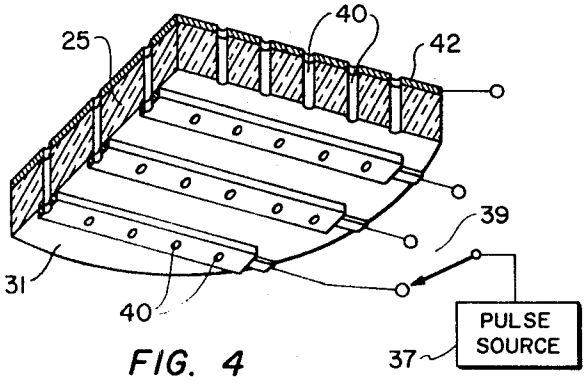


FIG. 4

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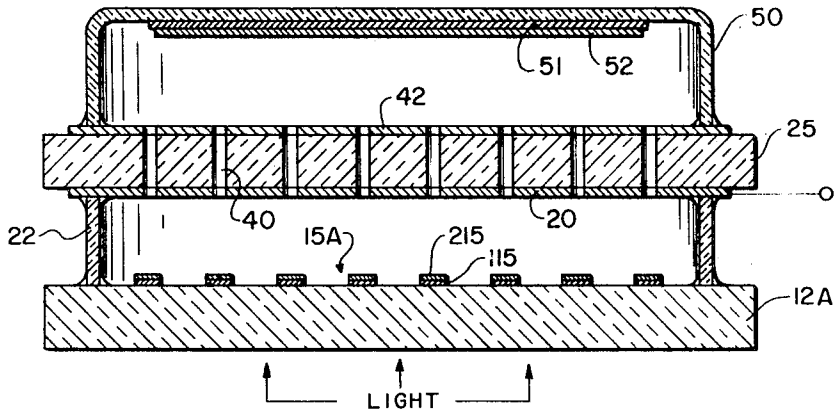


FIG. 5

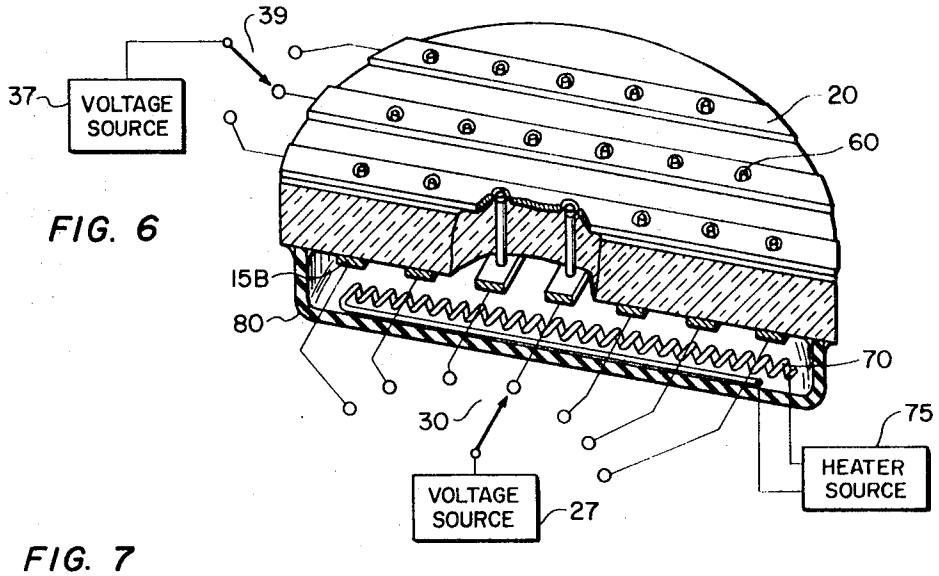
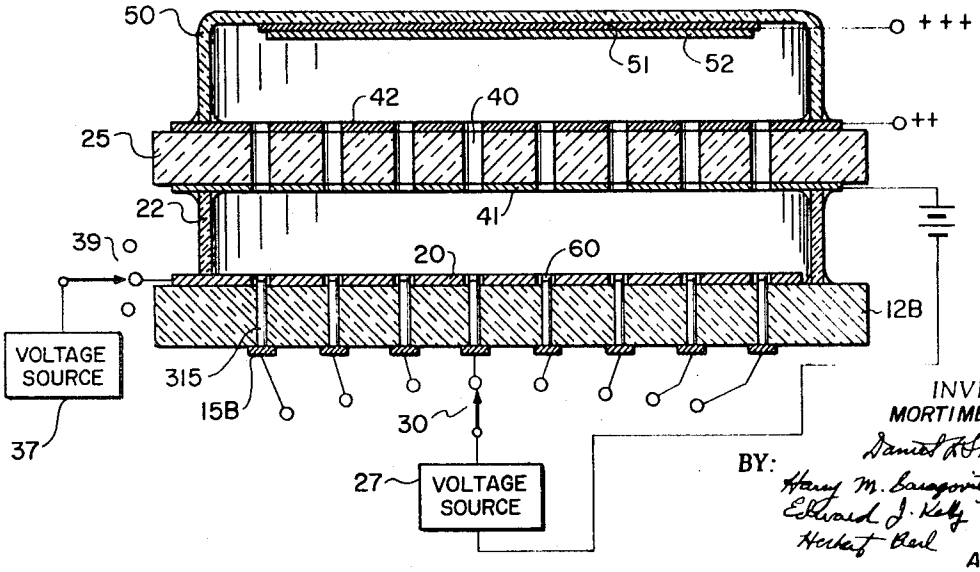


FIG. 6

FIG. 7



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FLAT DISPLAY TUBE WITH ADDRESSABLE CATHODE

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

This invention is concerned with active displays into which information is electronically fed in a sequential manner and which compose the information for presentation to an observer and which operate in the raster scan mode. For many years, the cathode-ray tube type display has performed ably and has several advantages, one of the most important of which is the relatively long persistence whereby a given elemental scanned area will remain luminous for at least the duration of the scanning (frame) period. In spite of the advantages of the cathode-ray tube as a display device, efforts have been made to replace the cathode-ray tube electronic display because of its high ratio of depth to display area diagonal normally required for adequate displays. This is particularly the case in military equipment in which more stringent requirements for spot size and distortion attain, in addition to the requirement for conservation of volume and weight. Emphasis in recent years has been given to electroluminescent panels and solid-state devices and techniques for achieving a flat panel display. Such devices, however, have many disadvantages, such as a relatively low light output, limitations in the spectrals output-eye response match, and short persistence. The latter characteristic limits the number of elements which can be excited during the frame period of requires latching means to keep excited elements on during the major portion of the frame period. Furthermore, some of these devices have limiting switching speeds which restrict the scanning rates obtainable. Consequently, efforts have been made to return to the electron-beam type of display device, while at the same time to minimize the depth factor which is the most serious drawback of this type of display. One such approach, using selective electron emitters at intersections of closed conductors, is described in an application for U.S. Letters Patent Ser. No. 639,928 of Crost, Shoulders and Zinn, entitled "Thin Electron Tube with Electron Emitters at Intersections of Crossed conductors," filed May 15, 1967 now U.S. Pat No. 3,500,102. In this application, an electronic display tube is described which includes a scannable cathode in which the section of the cathode directly opposite the selected light-emitting resolution element is activated so that only this section emits electrons, said electrons being emitted in a comparatively direct line to a fluorescent screen maintained positive with respect to the cathode. This type of cathode which can provide the scanning feature is achieved by making regular arrays of micron-size apertures in an insulator with field-emitting asperities on metallic strips within these apertures. A set of grid strips is formed orthogonal to the cathode strips with apertures in it corresponding to each of the apertures in the insulator. By applying a small positive bias voltage between the cathode and grid strips the emitters can be brought just below the voltage required or emission. By varying this voltage, positive on the selected grid strip and negative on the selected cathode strip, conduction will take place from the set of apertures located between the two selected strips With the small spacing between the grid and the anode, the electrons emerging from the grid aperture will strike a single spot on the phosphor corresponding geometrically to the emitting spot on the cathode. In such a device, it has been determined that it is necessary to obtain about 1 microampere per spot at the phosphor screen. This can be achieved, with a separation between crossed strips of about 1 micron; with a voltage of approximately 10 volts which results in an electric field of 10^6 volts per centimeter without assuming any field increase due to the shape of the asperities. The problem, however, is that it is difficult to fabricate a practical device of this type.

SUMMARY OF THE INVENTION

In accordance with the invention, a channel multiplier with a gain of the order of from 10^4 to 10^5 is used with the tube of the aforesaid application to obtain the same current per spot (approximately 1 microampere) at the phosphor screen with a much lower cathode current, that is, with a cathode mission of about 10^{-7E-4} to 10^{-7E-5} microamperes per asperity and, if the spacing between the multiplier and cathode is of the order of 0.002 mil, a voltage of about 100 volts can be used, the exact value depending upon the configuration and characteristic of the cathode asperity. In addition to facilitating practical construction, the technique according to the invention allows for lower cathode current density, thereby minimizing cathode design problems. In fact at this low current density it should be possible to utilize a cathode mechanism other than the field emission originally postulated. A photocathode or low-temperature thermionic cathode tube can be used. With these types of cathode a lower voltage is required for cathode emission, assuming the same separation of cathode and channel multiplier. With the photocathode, each of the cathode strips comprises an optically transparent electrode covered by a this layer of photoemissive material.

With the thermionic cathode, each of the cathode strips disposed on one surface of the substrate has several cathode pins disposed along the length thereof; these pins extend through the substrate and have the free ends coated with a thermionically emissive material. The coated ends of these pins are juxtaposed to openings in corresponding grid strips which are disposed on the opposite surface of said substrate and are orthogonal to the cathode strips. The cathode pins are heated by a heater mounted adjacent to the substrate.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing a first embodiment of the display tube;

FIG. **2** is a fragmentary view showing details of the cathode assembly of the device of FIG. **1**;

FIG. **3** is a view showing a modified version of the cathode assembly of FIG. **2**;

FIG. **4** is a view showing details of construction of the channel multiplier plate and grid assembly of the device of FIG. **1**;

FIG. **5** is a cross-sectional view of a second embodiment of the display tube using photoelectric emission;

FIG. **6** is a view showing a portion of the display tube using thermionic emission and;

FIG. **7** is a cross-sectional view of a display tube using the assembly shown in FIG. **6**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, a flat panel display device **10** is shown in FIGS. **1** and **2** which includes an electrically insulating substrate **12**, made, for example, of a ceramic. Disposed upon the upper surface **13** of this substrate is an array of parallel cathode strips **15** which may be made of germanium. As shown more clearly in FIG. **2** these cathode strips **15** have formed thereon clusters of germanium asperities or needles **16** which may be spaced in a more or less regular pattern along the length of the various cathode strips. The manner of forming these asperities on molybdenum is already known and may be by evaporating aluminum and then heating to remove the aluminum. Although the asperities may be formed over the entire surface area of the cathode strip, as shown in FIG. **3**, it is possible to selectively form the asperities only on regularly spaced portions of the cathode strips **15**, as shown in FIGS. **1** and **2**, by use of proper masking techniques, or by applying flash voltage between germanium cathode strips **15** and the grid strips **20** of the display device. ONe end of each of the cathode strips **15** can be brought out directly to the edge of the substrate; alternatively, connecting leads can be attached to the respective strips and brought out through the evacuated

inclosure bounded by the cathode substrate **12**, the ceramic ring **22** and the channel multiplier disc **25**. The ceramic ring **22** is sealed to the cathode substrate **15** and the multiplier disc **25** by frit seals. A pulse source **27** (see FIG. **2**) can be applied sequentially to the cathode strips, as by commutator means **30** shown schematically in FIGS. **1** and **2**. Spaced from the array of cathode strips **15** by ceramic ring **22** is the grid array which includes plurality of grid strips **20**, shown clearly in FIG. **4** and arranged orthogonally to the cathode strips **15**. Only one of these grid strips is visible in FIG. **1**. The channel multiplier disc **25** which contains several openings **40**, serves not only as an electron multiplier, but also serves as an accelerator to one surface **31** of which the array of grid strips **20** are mounted. The grid strips **20** are made of an electrically conducting material such as copper, nickel, etc. formed by evaporation upon the channel multiplier plate **25** through an appropriate mask. Due to the small size of the multiplier channels **40**, typically 5 to 10 micrometers, there are a plurality of channels in an area corresponding to a crossover point. For the sake of drawing simplicity, however, only one opening **40** in the channel multiplier plate **25** is indicated for each crossover point of the grid and cathode strips. The spacing between the cathode and grid strips can be of the order of 0.002 mils, as contrasted with the spacing of the order of micrometers between crossed grid and cathode strips of the device shown in the aforesaid patent application. As indicated diagrammatically in FIG. **4** the grid strips are connected through sequential switching means **39** to a pulse source of voltage **37**. By way of example, the pulses applied to the cathode strips **15** may be negative-going pulses of about 50 volts and the pulses applied to the grid strips **20** may be positive-going pulses of about the same order of magnitude. By using such pulses of different polarity, no electron emission will occur between a selected energized strip of one array and nonselected strips of the orthogonal array crossing the selected strip, i.e., only the point of intersection of simultaneously selected orthogonal strips will have sufficient potential difference to cause electron emission. One than can operate over a linear portion of the emission current vs. voltage characteristic and thereby avoid saturation.

The multiplier disc **25** which may be made of glass of the type which provides a prescribed electric resistance in the thickness direction, such as leaded glass, contains several channels **40** aligned with the crossover points of the grid and cathode strips. Such channel multiplier discs may be made by techniques similar to those used in making fiber optic plates, as by etching out the fibers in a fiber optic plate to leave a disc or plate containing many fine channels into which can enter the electrons which have been accelerated in the cathode-grid space. On the surface of the multiplier plate opposite that which supports the array of grid strips there is a uniformly evaporated metal film **42** which does not block the apertures **44** for egress of the electrons passing through the channels in the multiplier disc **25**. This electrode **42** is connected to a source **45** of DC voltage which, for example, may be of the order of +1000 volts. The electrons emitted from a selected localized region of the cathode, which is at the intersection of simultaneously energized cathode and grid strips, enter into the channel **40** of the multiplier disc **25** immediately opposite the source of electrons and, because of the voltage drop along this channel resulting from the voltages applied between the electrode **42** and the grid strips **20**, secondary emission of electrons occurs within this channel and the electron flux emanating from the channel is as much as 10^5 times greater than that entering the channel. The electrons after leaving a given channel are accelerated toward an anode or target **51** which is maintained at a relatively high positive potential, say 5 kilovolts, relative to the electrode **42** on the multiplier disc **25** by potential source **48**. The anode **51** is supported from a dome-shaped member **53** of optical transparent material sealed to the electrode multiplier plate, as by glass frit seals forming an evacuated chamber within the dome. The anode **51** is coated with a phosphor layer **52** which, when impinged upon by electrons emanating from a selected one of the channels **40** of the multiplier disc, gives rise to visible emission from the region impinged upon. It should be understood that the number of cathode and grid strips shown in FIGS. **1–4** are limited for reasons of drawing simplicity; actually many strips per inch would be used, depending upon the resolution desired.

Another type of display tube is shown in FIG. **5** which uses the electron flow from a photocathode. The multiplier disc **25** and anode dome **53** with its phosphor-coated target **51**, is the same as for the device of FIGS. **1–4**. As indicated in FIG. **5**, the cathode substrate **12A** includes the usual array of elongated cathode strips **15A**, which, however, differ from the cathode strips **15** in FIGS. **1–4**, in being made of an optically transparent or translucent material which is also electrically conductive. For example, the cathode strips **15A** of FIG. **5** may be tin oxide strips **115** coated with a photoemissive material **215** such as cesium or the trialkali antimonide. In this embodiment, the cathode substrate **12A** must be either optically transparent or optically translucent. A translucent material such as frosted glass may be used and can be flooded from the back side with a uniform light source. A translucent material sometimes is preferable to a transparent material since a greater diffusion of light over the surface can be obtained with a conventional light source. The cathode strips **15A** would be pulsed negatively in sequence. An array of grid strips **20** orthogonal to the array of cathode strips **15A** is supported on one surface of the multiplier disc **25**. The grid strips can be identical to those shown in in the device of FIGS. **1** to **4**. When an appropriate positive voltage pulse is supplied instantaneously to a selected one of these grid strips **20**, photoelectrons will be accelerated towards said selected grid strip. The region along the selected grid strip to which the photoelectrons will be accelerated depends upon which of the cathode strips is simultaneously energized.

A third embodiment of the invention using thermionic emission, is shown in FIGS. **6** and **7**. This device, like those already described, has the usual crossed arrays of cathode strips and grid strips, an electrode multiplier disc and an anode provided with a phosphor layer. The cathode structure of FIGS. **6** and **7** includes an electrically insulating substrate **12B** upon one surface of which is mounted a series of regularly arranged cathode strips **15B**. Attached to each of said cathode strips **15B** at regular intervals in a plurality of cathode pins **315**; the unattached ends of these cathode pins each comprise a supply **60** of thermionic emissive material, such as barium oxide. The cathode pins **315** pass through the cathode substrate **15B** and through aligned apertures **65** in a series of grid strips **20** orthogonal to the cathode strips **15B**. These grid strips are identical to those shown in the devices of FIGS. **1** to **5**, but are now deposited upon the opposite surface of the cathode substrate, rather than being mounted on the channel multiplier disc **25**. A heater coil **70**, energized from an appropriate DC heater voltage source **75**, is mounted adjacent the cathode substrate **12B** within a header **80** and brings the cathode pins **315** to the proper temperature for thermionic emission to take place from the emitter **60** when the appropriate voltage difference exists between the cathode pin **315** in question and selected grid strip **20**. Thermionic emission occurs from a cathode pine **315** disposed on a selectively energized cathode strip **15B** which lies at the intersection of a simultaneously energized selected grid strip **20**. Selection of cathode and grid strips can be made by means **30** and **39**. The electrons emitted from this selected cathode pin **315** are accelerated by a positive potential applied to electrode **41** and, after passing through the apertures **65** in the selected grid strip **20** which are opposite to the selected cathode pin, are accelerated by means of the continuous apertured electrode **42** and secondary emission occurs within the channels **40**. The potential of layer **42** may be of the order of 1 kilovolt positive with respect to layer **41**. The many electrons emanating from this channel are finally accelerated toward the anode **51** (supported from dome **53**) which is maintained still more positive than the potential on the multiplier disc electrode **42**. The region of the

anode phosphor screen **52** juxtaposed to the selected multiplier channel **40** from which the electrons emerge will then emit light.

In the thermionically emissive tube of FIGS. **6** and **7** it is possible to fabricate electrode **41** as a set of strips instead of the continuous electrode originally described. In this event both this array and the array of grid strips would be simultaneously pulsed by the positive-going pulses capacitively coupled by way of commutator means to the two arrays.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is, accordingly, desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electron display tube comprising an electrically insulating substrate, a first array of spaced uniform electrically conductive cathode strips mounted on one surface of said substrate, a second array of uniform electrically conductive grid strips arranged substantially orthogonal with said first array of cathode strips and containing apertures for passage of electrons emitted from said cathode strips, said grid strips being spaced from said cathode strips, an electron multiplier member spaced from said substrate and containing a multiplicity of apertures juxtaposed with the intersections of said cathode and grid strips, first supply means for providing an electric potential between a selected one of said grid strips sufficient to cause electron emission from the region of the selected cathode strip juxtaposed with said selected grid strip, means for providing a potential difference across the multiplier member for producing secondary emission of electrons within channels juxtaposed with said region of electron emission, an optically transparent target spaced from said multiplier member and including a phosphor layer, and means for accelerating the electrons passing through said channels onto said phosphor layer to produce luminescence of the area of said layer aligned with said region of electron emission.

2. An electron display tube according to claim **1** wherein said array of grid strips is mounted on a surface of said electron multiplier member facing said cathode strips.

3. An electron display tube according to claim **1** wherein said array of grid strips is mounted on the surface of said substrate opposite that upon which said array of cathode strips is mounted.

4. An electron display tube according to claim **1** wherein the thickness of said cathode strips is small compared with that of said substrate.

5. An electron display tube according to claim **1** wherein said array of grid strips is mounted on said multiplier member.

6. An electron display tube according to claim **1** wherein said means for accelerating include an electrode mounted on the surface of said multiplier member facing said target.

7. An electron display tube according to claim **1** wherein said substrate transmits light directed thereupon and said cathode strips are photoemissive.

8. An electron display tube according to claim **1** wherein said cathode strips have spaced groups of asperities formed thereon.

9. An electron display tube according to claim **1** wherein said cathode strips have mounted therealong spaced cathode pins having one end disposed within a corresponding aperture in said strips and coated at one end with a thermionically emissive material.

10. An electron display tube according to claim **7** further including a heater means for heating said material to the proper emitting temperature corresponding to the potential applied between said cathode pins and said grids strips.

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