United States Patent [19]

Schwartz

[11] **3,845,241**

[45] **Oct. 29, 1974**

[54] **TELEVISION DISPLAY PANEL HAVING GAS DISCHARGE CATHODO-LUMINESCENT ELEMENTS**

[75] Inventor: **James W. Schwartz,** Glenview, Ill.

[73] Assignee: **Zenith Radio Corporation,** Chicago, Ill.

[22] Filed: **Feb. 2, 1973**

[21] Appl. No.: **328,979**

[52] **U.S. Cl.**.... **178/7.3 D,** 313/108 B, 315/169 TV, 340/324 M

[51] **Int. Cl.** **H05b 37/00**

[58] **Field of Search** .... 178/7.3 D; 315/169 TV, 315/169 R; 340/324 M, 343; 313/108 R, 104, 105; 318/109

[56] **References Cited**

UNITED STATES PATENTS

2,249,016	7/1941	Lubszynski	313/105
2,595,616	5/1952	Toulon	178/5.4 R
2,760,119	8/1956	Toulon	315/169 TV
2,880,371	3/1959	Tosswill	315/169 TV
2,925,526	2/1960	McNaney	315/169 R
3,041,489	6/1962	Veith	313/68 D
3,137,802	6/1964	Gebel	313/104
3,408,532	10/1968	Hultberg	340/324 M
3,701,924	10/1972	Glaser	315/169 TV
3,743,879	7/1973	Kupsky	313/108 B
3,753,041	8/1973	Lustig	315/169 R

Primary Examiner—Robert L. Richardson
Assistant Examiner—Mitchell Saffian
Attorney, Agent, or Firm—John H. Coult

[57] **ABSTRACT**

This disclosure depicts cathodo-luminescent devices utilizing a gas discharge as the source of electrons, and television display apparatus employing an X–Y matrix of such devices as the picture elements. In each embodiment illustrated, the cathodo-luminescent display devices are depicted as each comprising a two-section gas cell. A gas discharge, serving as the electron source, is established in a first section between cathode means and anode means. Free electrons generated in the first section are drawn through openings in the anode means by a high gradient field in a second section and accelerated into impingement with a phosphor disposed on a viewing screen. Establishment of a gas discharge in the second section is precluded by appropriate selection of certain dimensions, gas pressure and accelerating voltage according to Paschen's law. Moderating means is provided in certain embodiments for causing the energy range of free electrons entering the second section to be narrow relative to the range of energies of free electrons generated in the gas discharge. A number of control grid arrangements and other features and details are disclosed.

15 Claims, 9 Drawing Figures

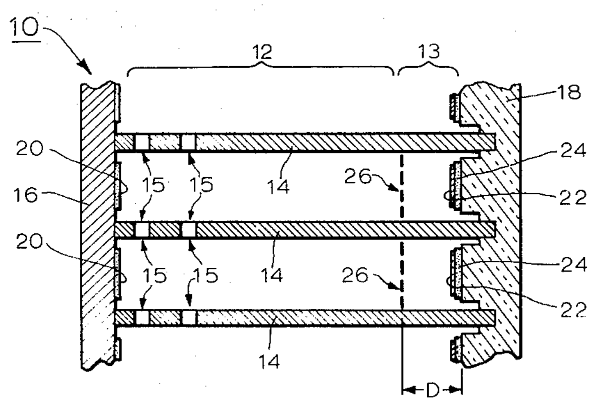


FIG. 1

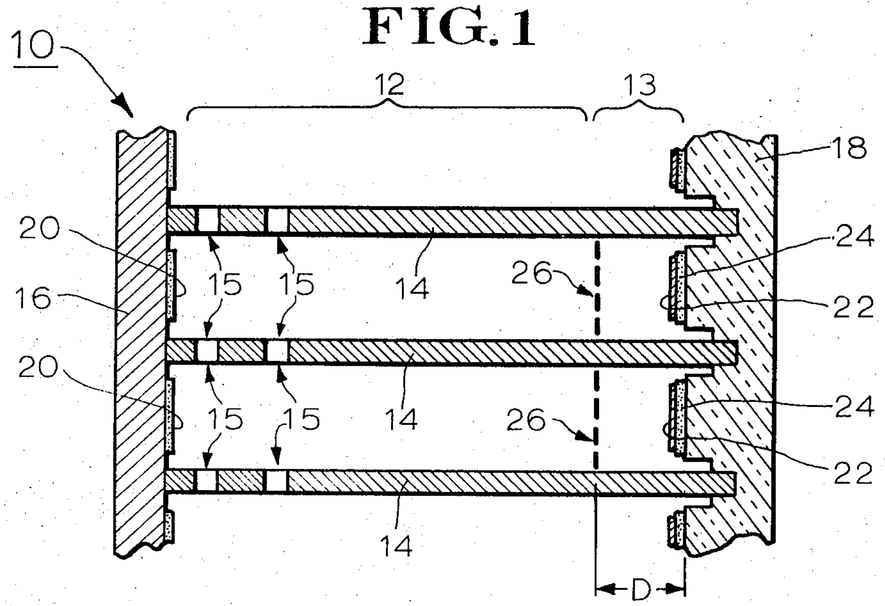
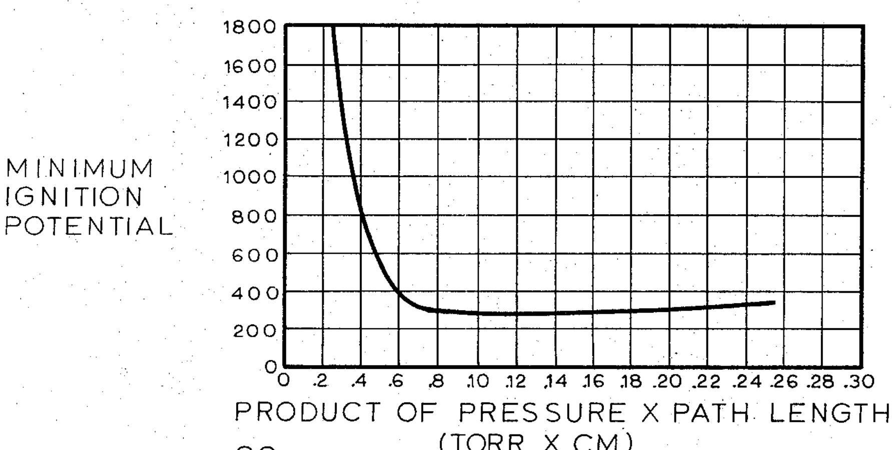


FIG. 2



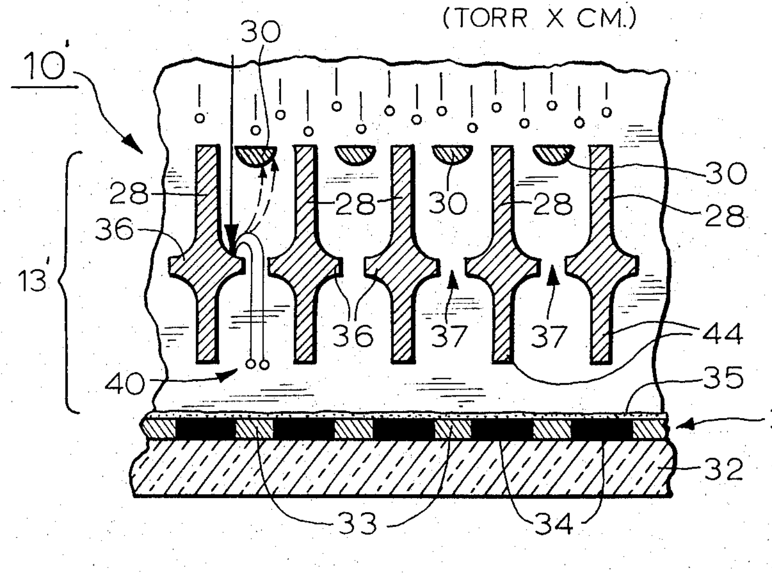


FIG. 3

FIG. 4

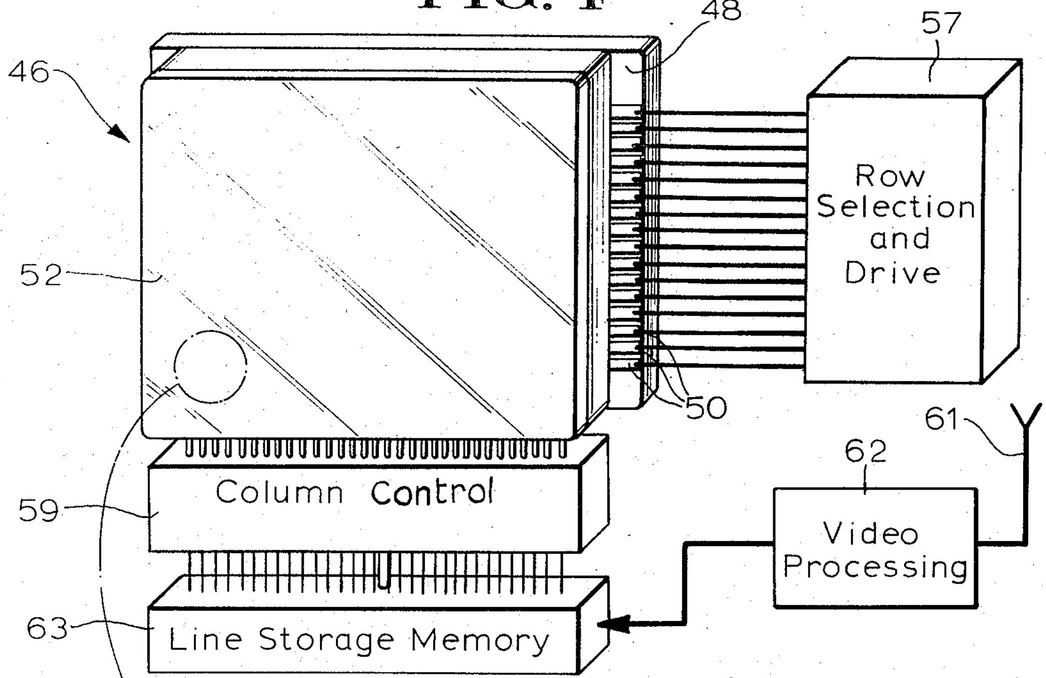


FIG. 5

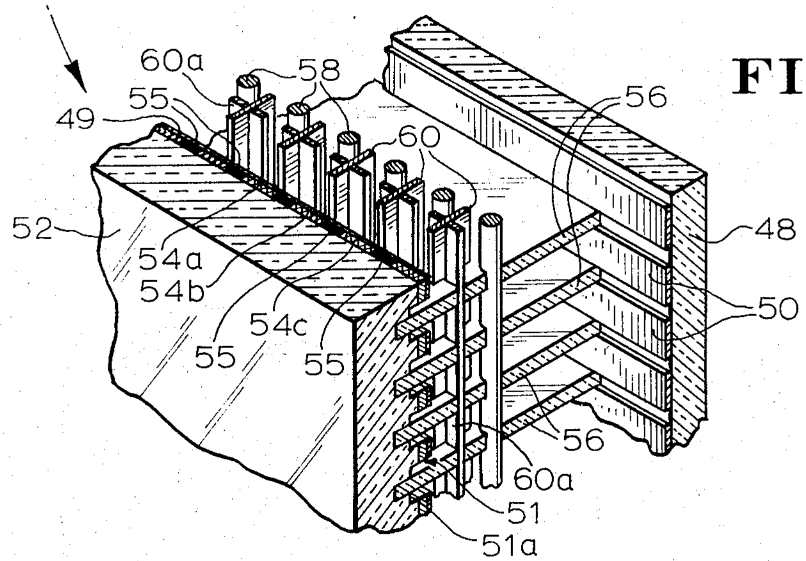


FIG. 5A

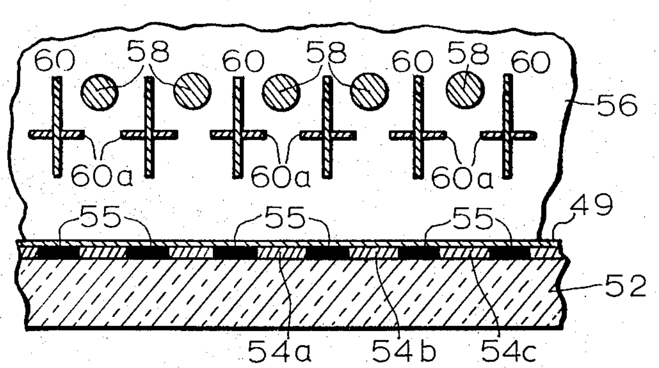


FIG. 6

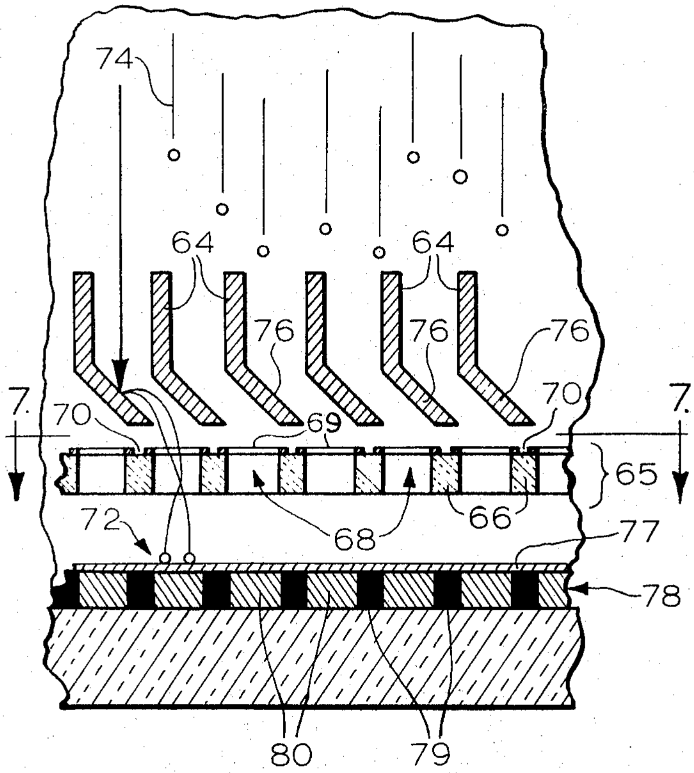


FIG. 7

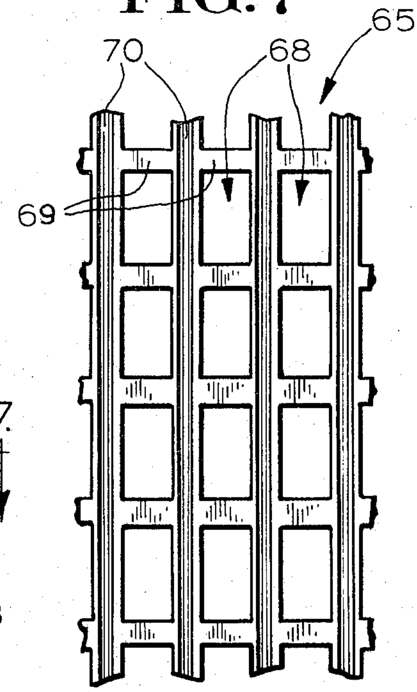
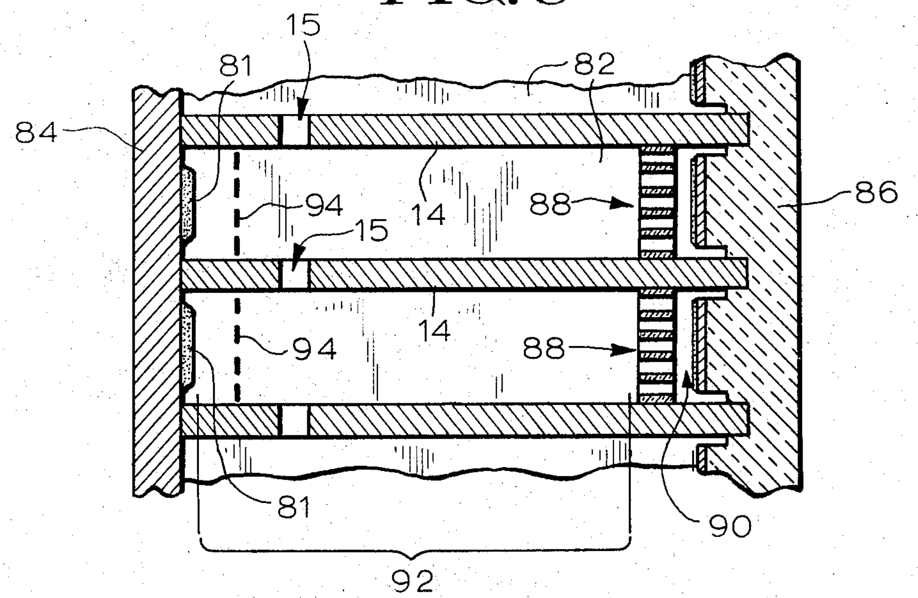


FIG. 8



TELEVISION DISPLAY PANEL HAVING GAS DISCHARGE CATHODO-LUMINESCENT ELEMENTS

BACKGROUND OF THE INVENTION

The evolution of television displays has been toward structures which are capable of reproducing ever larger and brighter images yet which are ever less bulky and lighter. Because of seemingly inherent limitations of cathode ray tubes which prevent attainment of large-screen, yet acceptably compact television receivers, other approaches, many of them radically different from cathode ray tubes, have been investigated.

It has been recognized that other avenues of investigation, to be viable, must potentially lead to display structures capable of reproducing images having adequate brightness, and acceptable color characteristics and luminous efficiency. A popular and widely investigated approach has utilized light-emissive elements arranged in X–Y matrices, selectively energized by means of row and column selectors and drivers. Light-emitting diodes and gas discharge devices and liquid crystal devices have been explored as possible light-emissive elements for use in matrix-type displays.

The utilization of light-emitting elements arranged in an X–Y matrix for row-column selection has imposed its own set of requirements, including the requirement that the individual picture elements be capable of individual selection without partial energization of unselected elements.

Certain approaches have been investigated in the past which attempt to take advantage of the high luminescent efficiency of the cathodo-luminescent phenomenon. Cold cathode devices have been constructed and tested but have not shown commercial viability, in part perhaps because of failure to provide an efficient electron source and an adequate way to assure mutually exclusive picture element selection. The gas discharge cell approach has been shown to provide adequate element selection capabilities because of its threshold switching characteristic, but as yet, has not been commercially demonstrated to provide adequate brightness and luminous efficiency, and satisfactory color characteristics.

This invention exploits the most desirable properties of both gas discharge devices and cathodo-luminescent devices. According to this invention, a gas discharge cathodo-luminescent device has a first section in which a gas discharge is established to provide a source of free electrons. The free electrons generated in the first section are accelerated to high energies in a second section wherein they bombard a light-emissive phosphor screen. This novel hybrid device thus exploits the favorable threshold switching properties and efficient electron supply of gas discharge devices and the favorable brightness, color selection and luminous efficiency properties of cathodo-luminescent devices.

U.S. Pat. No. 3,622,829, issued to Masanori Watanabe, discloses a flourescent screen display panel which represents an attempt to use a gas discharge to generate free electrons with an electron acceleration stage for accelerating free electrons to a light-emitting phosphor.

The apparatus disclosed by the Watanabe patent employs cathode and anode electrodes for establishing a sheet plasma oriented parallel to the display surface. In the disclosed system electrons are drawn transversely from the sheet plasma and caused to be accelerated transversely to a phosphor screen arranged parallel to the plasma.

The Watanabe system is considered to suffer from a number of shortcomings which have serious anti-commercial implications. First, the use of a sheet plasma causes the Watanabe device to be unacceptably inefficient and inherently susceptible to high power consumption. Secondly, striations and fluctuations which would degrade the displayed images are apt to occur in the sheet plasma. Thirdly, the fact that electrons are drawn transversely from the sheet plasma at different points along the potential gradient between cathode and anode electrodes which create the discharge is apt to cause an uneven distribution of electron energies across the panel.

Fourthly, the Wantanabe apparatus would inherently suffer from having an unacceptably wide range of electron velocities in the electron streams accelerated to the phosphor screen. Fifthly, the use of a sheet plasma spread over a very large panel area creates very serious mechanical support problems.

OBJECTS OF THE INVENTION

It is a primary object of this invention to provide improved light-emissive devices especially for use as light producing elements in television display apparatus and the like.

It is a less general object to provide light-emissive devices especially for use in television displays which are capable of high luminous efficiency and brightness, which offer a wide selection in the color characteristics of the emitted light, and which have a threshold-switching characteristic useful to achieve element selection in X–Y matrix television displays.

It is another object of this invention to provide cathodo-luminescent display apparatus which utilizes a gas discharge as a simple, reliable and efficient source of electrons, and yet which is not subject to the aforementioned drawbacks of devices using a sheet plasma as an electron source.

It is a specific object to provide a gas discharge cathodo-luminescent display device providing means for causing free electrons which are drawn from a gas discharge and accelerated to a phosphor screen to have a substantially narrower range of velocities than the free electrons generated in the gas discharge.

It is yet another object to provide a gas discharge cathodo-luminescent device having improved control grid means for controlling the flow of electrons to a phosphor screen.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional side view of a gas discharge cathodo-luminescent device following the principles of this invention;

FIG. 2 is a curve illustrating a relationship between pressure, path length and minimum ignition potential in a gas discharge cell; the curve is useful in understanding the present invention;

FIG. 3 is a schematic top sectional view which illustrates electron energy moderating means useful in gas discharge cathodo-luminescent devices according to this invention;

FIG. 4 shows schematically television display apparatus utilizing gas discharge cathodo-luminescent elements as shown in FIG. 1–3;

FIG. 5 is a schematic fragmentary perspective view, partly broken away, of the FIG. 4 display apparatus;

FIG. 5A is a fragmentary plan view of a portion of the FIGS. 4–5 panel;

FIG. 6 is a schematic top sectional view which depicts a variant on the embodiment shown in FIG. 3;

FIG. 7 is a view of a component of the FIG. 6 embodiment taken along lines 7—7 in FIG. 6; and

FIG. 8 is a side sectional view of another embodiment alternative to the FIG. 1 device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As briefly discussed above, the principles of this invention are preferably implemented in apparatus which employs a gas discharge structure as a simple, reliable and efficient source of free electrons and as a threshold switching mechanism to enable mutually exclusive element selection in an X–Y matrix of elements. The free electrons generated in the gas discharge are accelerated in an adjoining section into impingement with an electron-excitable phosphor screen. FIG. 1 illustrates one of many possible structural implementations of the principles of this invention. Before discussing FIG. 1, certain basic principles employed in devices according to this invention will be discussed.

Under appropriate gas pressure conditions, large potential differences may exist between electrodes without incurring a discharge, provided that such electrodes are spaced close enough. Stated another way, a discharge may occur at relatively low potential differences provided that the electrodes involved are spaced sufficiently far from each other. This situation might appear to be "unnatural." Nevertheless it is an attainable and practical condition. An explanation of the basic physics involved is as follows:

In a simple gas diode, ions impinge upon the cathode, releasing secondary electrons. The electrons are accelerated toward the anode. The probability of interaction with a gas atom in the intervening space depends upon the density (pressure) of gas molecules in that space and the length of the path. When an electron has gained sufficient energy in falling through the electric field along the cathode-to-anode path, it can ionize a gas atom thus freeing in additional electron and creating a "feedback" ion. The two electrons (the original one plus the newly formed one) proceed toward the anode, perhaps creating additional ion/electron pairs on the way. Some ions and electrons will be lost to the walls. In general each backward accelerated ion impinging upon the cathode will free an average of less than one electron — often perhaps as few as 1 electron for 10 ions. Hence, for a sustained discharge, each electron leaving the cathode must initiate an avalanche of ion/electron pair generating collisions such that enough ions are generated on the average to satisfy wall lossess and to generate collectively one new secondary electron at the cathode.

Obviously, if the density of gas is not sufficient to allow an adequate number of collisions along the cathode-to-anode path, a discharge cannot be maintained. Increasing the path length increases the probability of a collision at a given pressure. Raising the voltage difference helps in a marginal situation. This is primarily because the electrons will be accelerated to the minimum ionizing level sooner along the path, thus increasing the effective path length, and because occasional release of more than one electron per collision may occur. On the other hand, high velocity electrons may have reduced probability of ionizing. The net result is that if a path is too short for a given gas density, a self-sustained discharge cannot be maintained even when very high voltage differences exist in the space. This circumstance is classically described by a Paschen curve, illustrated in FIG. 2. This curve and other principles and details of gas discharge devices and their operation may be described in such works as "Gaseous Conductors, " by James Cobine, Dover Publications (1958).

FIG. 1 illustrates, in highly schematic form, a gas discharge cathodo-luminescent device 10 following the teachings of this invention. The device 10 is illustrated as comprising wall means defining an enclosure comprising a first section 12 and a second section 13. The enclosure is charged with an ionizable gas at a predetermined pressure. Suitable gases which may be employed are helium, hydrogen or neon. The walls defining the enclosure are shown in the FIG. 1 device as comprising side walls 14, a first end wall 16 and an opposite second end wall, here shown as a transparent viewing screen 18. Lateral walls for completing the enclosure are not shown in the interest of simplifying the explanation of the invention. Side walls 14 separate neighboring cells, but are provided with holes 15 which allow equalization of gas pressure and limited charged particle diffusion between adjacent cells.

At a first end of the device defined by the first end wall 16 is disposed a cathode 20 adapted to have a voltage V_0. A first or discharge anode 26 is disposed between the first end wall 16 and the screen 18. A second or high voltage anode 22 is disposed at the extreme opposite end of the enclosure from wall 16 and is adapted to receive a relatively high accelerating potential V_2. A phosphor layer 24 is disposed on the second anode 22. The phosphor material for the layer 24 may be selected from a large group of commercially available cathodoluminescent materials in accordance with its desired color and other characteristics.

As explained in detail below, the first anode 26 is adapted to receive an applied voltage V_1 which is substantially lower than the accelerating voltage V_2. The first anode 26 and the cathode 20 cooperate to establish a discharge in the enclosure. The voltage difference $V_1 - V_0$ is caused to have a predetermined magnitude effective to support a gas discharge between the cathode 20 and the first anode 26. The first anode 26 and the cathode 20 thus define a first section of the device 10 in which a supply of free electrons is generated. Detailed knowledge of gas discharge devices per se is available in such prior art works as the above-mentioned text by Cobine.

The first anode 26 and the second anode 22 cooperate to define a second section 13 of the device in which free electrons generated in the gas discharge established in the first section 12 are accelerated to high energies whereupon they bombard the phosphor layer 24 on the viewing screen 18. $V_2 - V_1$ may, for example, be in the order of 1,000 to 10,000 volts.

It is desirable that no part of the gas discharge established in the first section 12 of the device exist in the second section 13. Yet it is also important that means be provided for permitting free electrons generated in the gas discharge in section **12** to reach the second section **13** of the device. To this end, the first anode **26** preferably is structured to act as a barrier to the gas discharge established in the first section **12**, and yet be transmissive to electrons generated in the first section **12** of the device. In the FIG. **1** embodiment, the structure of the first anode **26** is shown schematically; a detailed discussion of more specific structures suitable for use as the first anode **26** will be discussed below.

Following Paschen's law, discussed in some detail above, the first anode **26** is preferably spaced from the second anode **22** a predetermined distance D which is insufficient, considering the gas pressure in the enclosure and the voltage difference $V_2 - V_1$ between the first and second anodes **26, 22** to support a gas discharge therebetween. Because the potential in second section **13** is higher than in first section **12**, positively charged ions generated in the first section **12** cannot enter second section **13**. Thus a discharge established in the first section **12** is isolated from second section **13** and by spacing second anode **22** relative to first anode **26** in accordance with Paschen's law, no tendency is provided for the establishment of a discharge between the first and second anodes. This suppresses discharges in the second section **13** of the device.

By the nature of the gas discharge established in the first section **12** of the device **10**, free electrons generated in the discharge arrive at the first anode **26** with generally axially directed paths of motion, but with energies ranging from almost zero to the full cathode-to-first anode **26** fall potential $(V_1 - V_0)$. This fall potential typically is in the order of several hundred electron volts. However, in some embodiments of this invention, it is undesirable for the free electrons entering the second stage **13** of the device for acceleration to the phosphor screen to have such a wide range of energies or initial velocities.

In accordance with one aspect of this invention, moderating means are provided for causing the free electrons admitted to the second section **13** of the device to have a substantially narrower range of velocities and energies than the free electrons generated in the gas discharge. FIG. 3 illustrates an alternative device **10'** including an electrode assembly **13'** implementing this invention. The electrode assembly **13'** provides a triple function: (1) it moderates electron velocities; (2) it acts as the above-described first anode; and (3) it serves as an instrumentality for modulating electron flow to the phosphor screen.

The electrode assembly is shown as comprising an array of electrodes **28**, discussed in detail below, and an array of novel control electrodes **30** cooperative with the electrodes **28**. The control electrodes **30** serve, in a way to be described below, to control the flow of electrons to the phosphor screen.

A phosphor screen **31** is shown as comprising a transparent base **32** on which is disposed phosphor areas **33** separated by optically non-reflective "guard band" areas **34**. An electrically conductive layer serving as the high voltage (second) anode **35** is disposed upon the areas **34** and **33**.

The moderating anode will now be described in detail. The electrodes **28** constituting the anode are each shown as having a generally cross-shaped configuration and can be thought of, in one sense, as comprising a baffle structure which is substantially less transmissive to high energy electrons than to low energy electrons. Baffling is achieved in the FIG. **3** embodiment by the cooperative configuration of the electrodes **28** and the control electrodes **30** which jointly act to shadow the phosphor screen **31**. High energy electrons generated in the gas discharge in section **12** (see FIG. **1**), travel in relatively straight lines and cannot pass into the second section **13'** of the device, but rather will be blocked either by the skirts **36** on the electrodes **28** or by the control electrodes **30**. Relatively low energy electrons, however, being more influenced by localized field patterns around the electrodes **28**, will be drawn through the openings **37** formed between the electrodes **28** and will pass into the second section **13'** of the device **10'**.

In accordance with an aspect of this invention, the electrodes **28** are caused to be capable of generating secondary electrons when bombarded by high energy electrons. To this end, the electrodes are preferably formed from a material such as iron with a thin gold electroplated outer layer. By this expedient, high energy electrons, upon hitting the electrodes **28**, are stopped but generate low energy secondary electrons which are drawn through the openings **37**. Thus, only the relatively slow secondary electrons generated by first electrons which hit electrode **28**, or relatively slow electrons from the gas discharge are admitted to the second section **13'** of the device **10'**. The electrons accelerated to the screen are thus caused, by the operation of the described moderating means, to fall within a much narrower range of energizes than exist in the gas discharge. Because, on the average, generally more than one secondary electron is generated for each primary electron striking electrode **28**, the device is much more efficient than a simple velocity selector which would merely transmit only the small proportion of slow electrons emerging from the gas discharge.

The electrodes **28** may all be operated at a common potential, for example 400–800 volts above cathode potential V_0. The combination of the array of electrodes **28** and control electrodes **30** presents a barrier not only to high energy primary electrons generated in the gas discharge but also to ultra-violet radiation produced in the first section **12** of the device.

The electrodes **28** also serve an important function in electrically isolating the rear first section of the device from the forward electron accelerating section **13'**, thus preventing the potential of the second anode **35** from severely influencing conditions in the discharge.

The control electrodes **30** will now be discussed in more detail. As described above, in the illustrated FIG. **3** embodiment, the control electrodes **30** cooperate with the electrodes **28** in blocking the passage of high energy electrons and thus in this capacity comprise part of the moderating means constituting one aspect of this invention. The primary function of the control electrodes **30**, however, is to provide a mechanism for modulating the flow of electrons from the gas discharge in the first section of the device to the phosphor screen **31**.

The control electrodes **30** may be operated in a number of modes. By operating the control electrodes **30** at a potential more positive than the potential of the electrodes **28**, secondary electrons (shown illustratively at **40**) generated upon impingement with the skirts **42** on the electrodes **28** are drawn to and collected by the control electrodes **30.** Thus, the slow secondary electrons are prevented from escaping through the openings **37** and into the second section **13'** of the device **10.**

The portions **44** of electrodes **28** extending beyond openings **37** toward the screen **31** serve to reduce the magnitude of the acceleration field in the openings **37,** thereby increasing the sensitivity of the control electrodes **30.**

It has been found that a potential on the electrodes **30** of only a few volts positive (relative to the potential on electrodes **28**) is required to completely cut off the flow of electrons to second section **13'** of the device. The control range has been found to typically vary between 5 and 50 volts depending upon the geometric design parameters and other factors.

It has been found that negative voltages (relative to the potential of electrodes **28**) are also effective in controlling the electron beam reaching the phosphor screen. In this case retarding fields are created which return slow secondary electrons back to electrodes **28.** The sensitivity for negative control potentials is about the same as for positive potential control.

Some electron multiplication takes place at electrodes **28.** Even in the presence of the loss of some rays, the ratio of maximum output current from electrodes **28** to input current has experimentally been found to be in the order of unity.

Thus, in summary, the electrodes **28** perform several functions: (1) they electrically shield the discharge region (the first section **12** in FIG. **1**) from the high fields of the final electron acceleration region (the second section **13** or **13'**); (2) in cooperation with associated cathode electrodes **20** they produce long, narrow, inline, front-to-back gas discharge electron sources; (3) they block the direct flow of high velocity electrons from the discharges into the acceleration spaces while passing slow electrons, and thus moderate the velocity range of electrons entering the acceleration regions; (4) they shield ultra-violet radiation from surfaces or gas atoms that are in the high field acceleration regions; (5) they provide sources of low velocity electrons which are capable of low voltage modulation; (6) they provide a plurality of collimated, individuallly modulatable elemental electron streams; (7) they provide means for individually modulating each of these elemental electron streams; and (8) they assist in producing an efficient ratio of output electron current to input current.

In the above-described structures and other structures yet to be described, there is provided, inter alia, barrier means for shielding the discharge region from the electron acceleration region, moderating means for moderating the range of electron velocities, ultra-violet radiation shielding means, electrode means for establishing a gas discharge and means for modulating the flow of electrons to the phosphor screen. In the structures illustrated and described herein, certain elements perform combined functions — for example, in FIG. **3** the illustrated control electrodes **30** serve also to block ultra-violet radiation and high velocity electrons; the electrodes **28** serve as moderating means, block ultraviolet radiation and act as the anode electrodes in the establishment of the gas discharge. Nevertheless, it is within the compass of this invention that separate means may be provided to perform the described different functions. Alternatively, other structures may be provided to perform combinations of the described functions different than those described.

It is contemplated that the cathodo-luminescent apparatus described above may be incorporated into a television receiver. FIG. **4** is a schematic perspective view of a television display panel **46** constituting a part of a television receiver. The panel **46** incorporates an X–Y matrix of cathodoluminescent devices of the nature shown in FIGS. **1–3** and described above. FIGS. **5** and **5A** represent enlarged views, partially cut away, of a portion of the FIG. **4** panel. The display panel **46** is illustrated as comprising a rear panel wall **48** on which is disposed a vertical array of horizontally oriented line cathodes **50.** At the forward end of the panel **46** there is provided a transparent faceplate **52** on the back surface of which is disposed a horizontal array of vertically oriented phosphor strips **54*a*, 54*b*, 54*c*.** In a color television application, the phosphor strips are preferably red-emissive, green-emissive and blue-emissive, in repeating series and are separated by narrow guard bands of optically non-reflective material. A conductive layer serving as the high voltage anode **49** is disposed on the phosphor strips and guard bands **55.**

Disposed between the rear panel wall **48** and the faceplate **52** is a series of vertically spaced, horizontally oriented cell walls **56** which are affixed in sealing relationship with the rear panel wall **48** and in grooves **51** in the faceplate **52.** In cooperation with panel side walls (not shown), walls **56** define a line-wise extending cell **53.**

The cell walls **56** constitute regularly occurring structural members for supporting the faceplate **52.** By this arrangement, atmospheric pressure forces are opposed periodically across the entire device surface rather than only at its periphery. This allows the use of thin, lightweight wall members and renders very large panels practical. As in the FIG. **1** embodiment, the grooves have lands **51*a*** which space the walls **56** from the high voltage second anode **49** on the back of the faceplate **52.** This is done to provide an adequate leakage path between the high potential of the second anode **49** (typically 1 to 10 KV) and the much lower potential of moderating means — first anode structure (typically 400 to 900 volts), described below.

Gas discharge elemental cells for implementing the principles of this invention may take the form of elongated cells extending across a complete or partial display line or a discrete unit element cell. The illustrated preferred embodiment, shown in FIGS. **4, 5** and **5A,** employs the preferred line-wise extending cell which encompasses the entire width of the panel **46.** The FIGS. **4–5A** panel is illustrated as including control electrodes **58** analagous to the control electrodes **30** in the FIG. **3** embodiment but having a circular rather than a truncated circular cross-sectional form. Moderating means are shown as including an array of electrodes **60** with skirts **60*a*** analogous to the electrodes **28** with skirts **36** in the FIG. **3** embodiment, but having a simplified cross-shaped cross-sectional configuration. The functions performed by the control electrodes **58** and the electrodes **60** are generally the same as those provided by the control electrodes **30** and the electrodes **28** in the above-described structures.

As can be seen in FIG. **4,** the control electrodes **58** and the cathodes **50** span the panel **46** and extend somewhat beyond in order that they be electrically accessible. The electrodes **60** are, of course, also preferably accessed to the exterior of the sealed enclosure to facilitate application of appropriate anode voltage. The electrodes **58** and **60** are sealed in the walls **56.**

Row selection and drive circuitry **57** and column electron current control circuitry **59** are shown for providing a modulated raster scan of the panel **46.** The row selection and drive circuitry **57** and column control circuitry **59** may be constructed following principles revealed in the prior art.

In operation, a discharge is established in the uppermost horizontally extending line cell by application of appropriate potentials on the uppermost of cathodes **50** and/or electrodes **60.** A line of video information which has, for example, been received by an antenna **61,** been processed appropriately in a processor **62,** and been stored in line storage memory **63,** is applied in parallel to a full row of light-emissive devices. The video information is applied to the control electrodes **58.** The line of video information is maintained for a horizontal line display period. In an alloted retrace time, the discharge is commuted downward to the adjacent cell or two cells downward depending upon the means for effecting vertical raster interlace. A second line of video information which has been stored in the memory **63** is applied to the second video line. A complete vertical scan of the panel to display a full video picture is accomplished in this manner.

If output light of sufficient intensity can be obtained from the cathodo-luminescent cells in devices by displaying only during the horizontal retract period, one set only of signal storage elements in the memory **63** is required. If insufficient intensity is obtained, information must be simultaneously written into one set of storage elements while another buffer set controls the display. Vertical commutation may be accomplished using discrete or multi-phase scanning signals.

An alternative first anode structure is depicted in FIG. **6.** FIG. **6** illustrates an array of electrodes **64** which perform generally the functions of the electrodes **28** in FIG. **3** and electrodes **60** in FIGS. **4–5A.** An apertured control grid member **65,** shown in more detail in FIG. **7,** is registered with electrodes **64** to accomplish grid control of the secondary electrons generated. The control grid member **65** is preferably fabricated from a dielectric sheet **66** having electron-transmissive openings **68** therein. The sheet **66** has disposed thereon an electrically conductive layer **69** which has strips **70** thereof removed in order to insulate columnar portions of the layer to enable column control of the electron streams.

As shown in FIG. **6,** secondary electrons **72** generated by high velocity electrons **74** impinging on angled portions **76** of the electrodes **64** are drawn to phosphor screen **78** by the voltage on anode **77.** In the FIG. **6** embodiment, the screen **78** may be similar in structure and function to the screens shown in FIGS. **3, 4** and **5,** however the optically non-reflective strips **79** are narrower to correspond with the smaller interstrip spacing of the phosphor areas **80** in the FIG. **6** embodiment.

FIG. **8** depicts yet another embodiment of the invention. In FIG. **8** structure, line cathodes **81** extend horizontally across the panel as in the above-described embodiments, but lateral inter-element cell walls **82** are provided which mate in sealing relationship with horizontally extending wall members **84** to break up the otherwise line-width discharge regions into discharge regions of elemental (spot) size. That is, vertical as well as horizontal partitions confine the discharge over at least part of its axial length. Perforated first anodes **88** serve to electrostatically separate the high field acceleration regions **90** from the low field discharge regions **92.** Some axial extension of the anodes **88** is desirable to effect adequate isolation of the two sections. Either a thick perforated member, or two spaced mesh members have been found suitable for this purpose.

Grids **94,** which may consist of an array of vertically extending apertured conductive strips, are provided to act as element modulators. Each grid **94** controls the discharge current in the cell containing it. In this embodiment electrons from the discharge regions **92** pass through the first anode **88** into the high field regions **90** without further velocity or amplitude modification. Hence the screen current at each element is directly proportional to and is controlled by the elemental discharge current.

The invention is not limited to the particular details of construction of the embodiments depicted and other modifications and applications are contemplated. For example, it has been found that interpositioning of one or more grids in the intervening space between anode electrode **26** and cathode **20** can be beneficial. A grid located near the cathode, or near the anode, allows sensitive control of the discharge and induces a smooth transfer from "on" to "off" states. Under certain circumstances as little as **10** volts are required for the complete modulation range. Certain other changes may be made in the above-described methods and apparatus without departing from the true spirit and scope of the invention herein involved and it is intended that the subject matter in the above depiction shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A cathodo-luminescent device comprising:

wall means defining an enclosure for receiving an ionizable gas at a predetermined pressure, said wall means having opposed first and second ends; pg,21

cathode means disposed at said first end of said enclosure and adapted to have a voltage V_0;

high voltage anode means disposed at said second end of said enclosure and adapted to receive a relatively high accelerating voltage V_2;

phosphor means disposed at said high voltage anode means for emitting light when bombarded by high energy electrons accelerated to said high voltage anode means; and

discharge anode means adapted to receive an applied voltage V_1 substantially lower than said accelerating voltage V_2, $V_2 - v_1$ being of a predetermined magnitude effective to accelerate free electrons to energy levels capable of exciting said phosphor means to emit light, $V_1 - V_0$ being of a predetermined magnitude effective to support a gas discharge between said cathode means and said discharge anode means, said discharge anode means being disposed directly between said first and second ends of said enclosure and spaced from said high voltage anode means a predetermined distance which is insufficient, considering said gas pressure and said voltage difference $V_2 - V_1$ between said high voltage anode means and said discharge anode means to support a gas discharge therebetween, said discharge anode means defining electron-transmissive openings for permitting free electrons generated in a discharge established between said cathode and said discharge anode means to pass through said discharge anode means and to be accelerated by said high voltage anode means into impingement with said phosphor means.

2. The apparatus defined by claim 1 including control means within said enclosure adapted to receive a variable electrical signal for controlling the flow of electrons to said phosphor means.

3. The apparatus defined by claim 1 including moderating means disposed between said first and second ends of said enclosure for causing free electrons accelerated from said discharge anode means to said high voltage anode means to have a substantially narrower range of energies than the range of energies of the free electrons generated in the gas discharge.

4. The apparatus defined by claim 3 wherein said functions of said discharge anode means and said moderating means are combined in a structure comprising baffle means substantially less transmissive to high energy electrons than to low energy electrons.

5. The apparatus defined by claim 4 wherein said structure is arranged so as to generate secondary electrons when struck by high energy electrons.

6. A cathodo-luminescent device comprising:

wall means defining an enclosure fo receiving an ionizable gas at a predetermined pressure, said wall means having first and second ends;

cathode means disposed at said first end of said enclosure and adapted to have a voltage V_0;

high voltage anode means disposed at said second end of said enclosure and adapted to receive a relatively high accelerating voltage V_2;

phosphor means disposed at said high voltage anode means for emitting light when bombarded by high energy electrons accelerated to said high voltage anode means; and

discharge anode means including a secondary electron emissive surface material and adapted to receive an applied voltage V_1 substantially lower than said accelerating voltage V_2, $V_2 - V_1$ being of a predetermined magnitude effective to accelerate free electrons to energy levels capable of readily exciting said phosphor means to emit light, $V_1 - V_0$ being of a predetermined magnitude effective support a gas discharge between said cathode means and said discharge anode means, said discharge anode means being disposed directly between said first and second ends of said enclosure and spaced from said high voltage anode means a predetermined distance which is insufficient, considering said gas pressure and said voltage difference $V_2 - V_1$ between said high voltage anode means and said discharge anode means, to support a gas discharge therebetween, said discharge anode means defining electro-transmissive openings which are substantially less transmissive to high energy electrons than to low energy electrons for permitting relatively low energy free electrons generated in the gas discharge and secondary electrons generated at said second anode means to be drawn through said discharge anode means and accelerated by said high voltage anode means into impingement with said phosphor means.

7. The apparatus defined by claim 6 including control grid means adapted to receive a variable electrical signal for controlling the flow of electrons to said phosphor means, said control grid means cooperating with said discharge anode means to control the flow of electrons through said openings.

8. Television display apparatus for reproducing an image represented in an input video signal, comprising:

an array of selectively addressable cathodoluminescent elements, each comprising:

wall means defining an enclosure for receiving an ionizable gas at a predetermined pressure, said wall means having opposed first and second ends,

cathode means disposed at said first end of said enclosure and adapted to have a voltage V_0,

high voltage anode means disposed at said second end of said enclosure and adapted to receive a relatively high accelerating voltage V_2,

phosphor means disposed at said high voltage anode means for emitting light when bombarded by high energy electrons accelerated to said high voltage anode means,

discharge anode means adapted to receive an applied voltage V_1 substantially lower than said accelerating voltage V_2, $V_2 - V_1$ being of a predetermined magnitude effective to accelerate free electrons to energy levels capable of exciting said phosphor means to emit light, $V_1 - V_0$ being of a predetermined magnitude effective to support a gas discharge between said cathode means and said discharge anode means, said discharge anode means being disposed directly between said first and second ends of said enclosure and spaced from said high voltage anode means a predetermined distance which is insufficient, considering said gas pressure and said voltage difference $V_2 - V_1$ between said high voltage anode means and said discharge anode means, to support a gas discharge therebetween, said discharge anode means defining electron-transmissive openings for permitting free electrons generated in a discharge established between said cathode and said discharge anode means to be drawn through said discharge anode means and accelerated by said high voltage anode means into impingement with said phosphor means, and

control means within said enclosure for controlling the flow of electrons to said phosphor means; and

means responsive to an input video signal and coupled to said control means for selectively addressing said elements and for applying said video signal thereto to cause said video signal to be reproduced as a spatially varying light image.

9. The apparatus defined by claim 8 including moderating means disposed between said first and second ends of said enclosure for causing free electrons accelerated from said discharge anode means to said high voltage anode means to have a substantially narrower range of initial energies than the range of energies of the free electrons generated in the gas discharge.

10. The apparatus defined by claim 9 wherein said functions of said discharge anode means and said moderating means are combined in a structure comprising baffle means substantially less transmissive to high energy electrons than to low energy electrons.

11. The apparatus defined by claim 10 wherein said structure is arranged so as to generate secondary electrons when struck by high energy electrons.

12. The apparatus defined by claim 9 wherein said cathodo-luminescent elements extend sideways to encompass one television line.

13. The apparatus defined by claim 9 wherein said cathodo-luminescent elements and said control means are arranged in an X–Y matrix each defining one image element,

14. Television display apparatus for reproducing an image represented by an input video signal, comprising:

an array of selectively addressable cathodo-luminescent elements, comprising:

wall means defining an enclosure for receiving an ionizable gas at a predetermined pressure, said wall means having opposed first and second ends,

cathode means disposed at said first end of said enclosure and adapted to have a voltage V_0,

high voltage anode means disposed at said second end of said enclosure and adapted to receive a relatively high accelerating voltage V_2,

phosphor means disposed at said high voltage anode means for emitting light when bombarded by high energy electrons accelerated to said high voltage anode means, and

discharge anode means composed of a secondary electron-emissive material and adapted to receive an applied voltage V_1 substantially lower than said accelerating voltage V_2, $V_2 - V_1$ being of a predetermined magnitude effective to accelerate free electrons to energy levels capable of readily exciting said phosphor means to emit light, $V_1 - V_0$ being of a predetermined magnitude effective to support a gas discharge between said cathode means and said discharge anode means, said discharge anode means being disposed directly between said first and second ends of said enclosure and spaced from said high voltage anode means a predetermined distance which is insufficient, considering said gas pressure and the voltage difference $V_2 - V_1$ between said high voltage anode means and said discharge anode means, to support a gas discharge therebetween, said discharge anode means defining electron-transmissive openings which are substantially less transmissive to high energy electrons than to low energy electrons for permitting relatively low energy free electrons generated in the gas discharge and secondary electrons generated at said discharge anode means to be drawn through said discharge anode means and accelerated by said high voltage anode means into impingement with said phosphor means, and

control means within said enclosure for controlling the flow of electrons to said phosphor means; and

means responsive to an input video signal and coupled to said control means for selectively addressing said elements and for applying said video signal thereto to cause said video signal to be reproduced as a spatially varying light image.

15. A cathodo-luminescent television display device, comprising:

means defining an enclosure for receiving an ionizable gas at a predetermined pressure;

a viewing screen at one end of said enclosure including first anode means adapted to receive a relatively high accelerating voltage V_2 and having disposed thereon phosphor means of pre-selected spectral characteristics for emitting light when bombarded by high energy electrons;

cathode means within said enclosure disposed in a plane parallel to said screen and adapted to have a voltage V_0;

electrode means within said enclosure including gas discharge barrier means and discharge anode means both disposed between and oriented parallel to said cathode means and said screen, said discharge anode means being adapted to receive an applied voltage V_1 substantially lower than said accelerating voltage V_2, $V_2 - V_1$ being of a predetermined magnitude effective to accelerate free electrons to energy levels capable of readily exciting said phosphor means to emit light, $V_1 - V_0$ being of a predetermined magnitude effective to support a gas discharge between said cathode means and said discharge anode means, said discharge anode means being spaced from said high voltage anode means a predetermined distance which is insufficient, considering said gas pressure and said voltage difference $V_2 - V_1$ between said high voltage anode means and said discharge anode means, to support a gas discharge therebetween, said discharge anode means defining electron-transmissive openings for permitting free electrons generated in a discharge established between said cathode and said discharge anode means to be drawn through said discharge anode means and accelerated by said high voltage anode means into impingement with said phosphor means;

control grid means within said enclosure for controlling the flow of electrons to said phosphor means; and

means responsive to an input video signal and coupled to said control grid means for selectively addressing said elements and for applying said video signal thereto to cause said video signal to be reproduced as a spatially varying light image.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,845,241 Dated October 29, 1974

Inventor(s) James W. Schwartz

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

Column 8, line 20, after "bands" insert --55--.

Column 9, line 29, delete "in" and substitute --or--.

Column 10, line 40, delete "pg, 21".

Column 10, line 53, delete "$_{v1}$" and substitute --V_1--.

Column 11, line 30, after "having" insert --opposed--.

Signed and sealed this 18th day of February 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks