Sept. 2, 1958 J. T. McNANEY 2,850,657

CATHODE RAY TUBE CURRENT AMPLIFYING MEANS

Filed Aug. 20, 1956 2 Sheets-Sheet 1

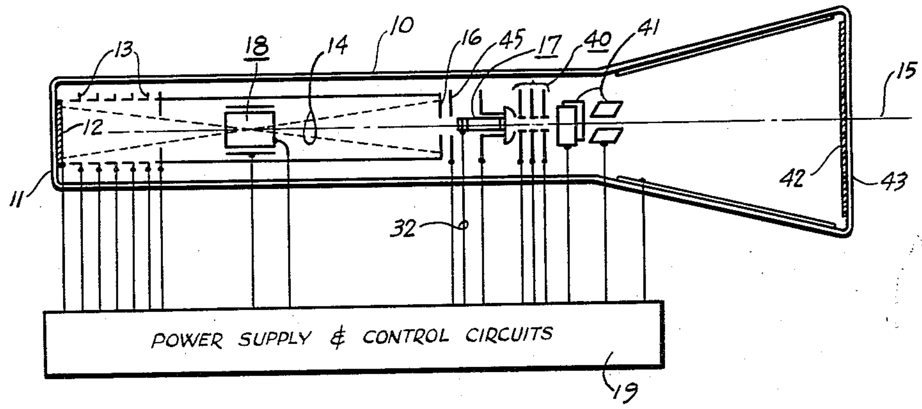

FIG_1

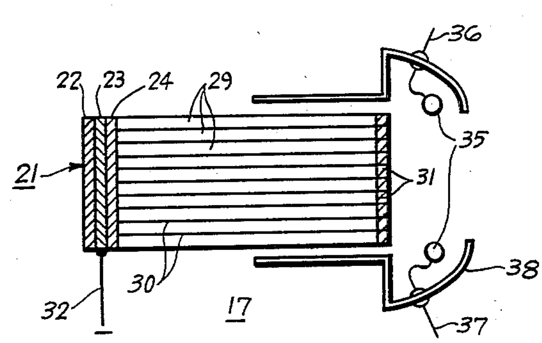

FIG_2

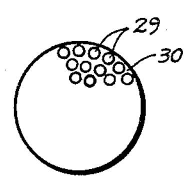

FIG_3

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CATHODE RAY TUBE CURRENT AMPLIFYING MEANS

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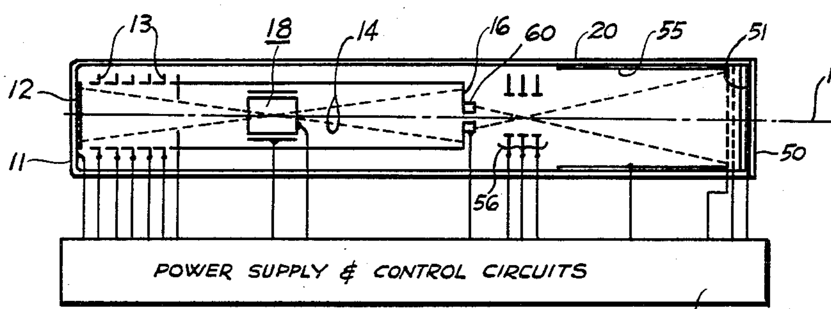

FIG_4

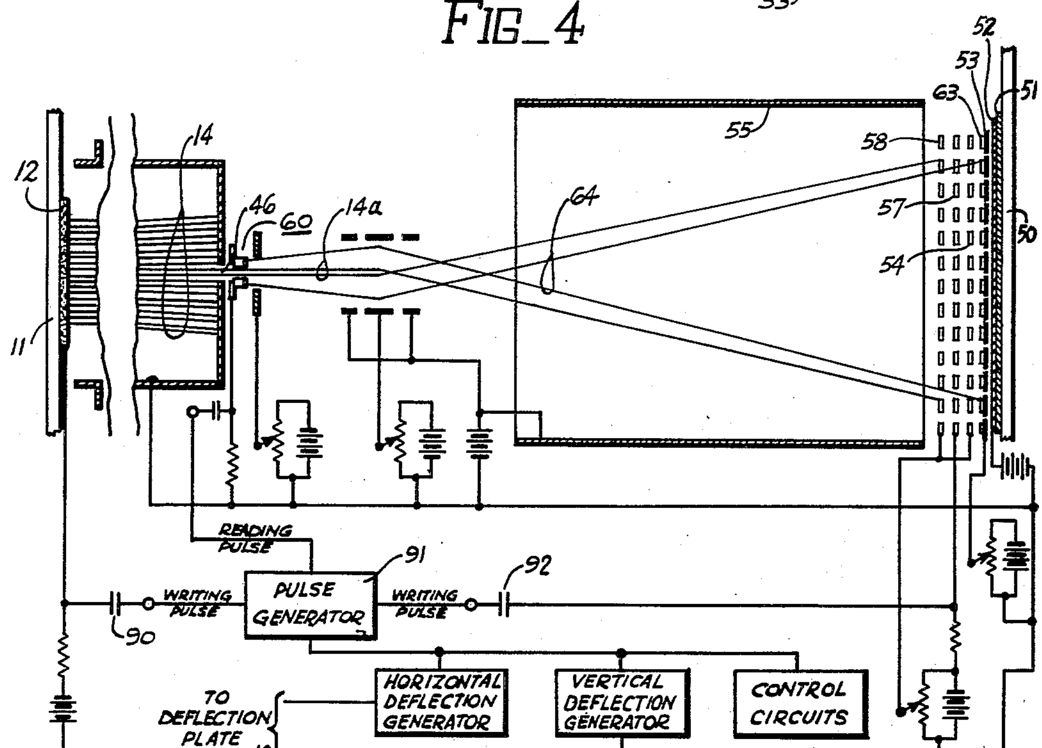

FIG_5

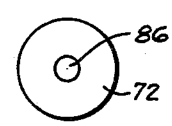

FIG_6

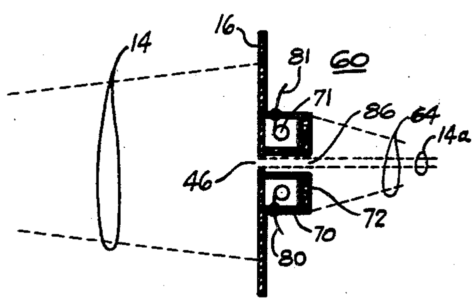

FIG_7

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CATHODE RAY TUBE CURRENT AMPLIFYING MEANS

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Application August 20, 1956, Serial No. 604,931

7 Claims. (Cl. 313—65)

This invention relates generally to apparatus for amplifying the useful current of a beam of electrons in a cathode ray tube. More particularly the invention relates to means by which the electron emission or current density of a photo-cathode may, in effect, be increased over that initially available from such a source.

In my application for patent, Serial No. 568,236, assigned to the common assignee hereof, a device utilizes a primary electron beam which is derived from a photo-emissive cathode. The photo-emissive cathode, however, has a rather low current density output with limited utility. The device will have greater utility if the intial current density obtained from the photo-cathode can be increased over that presently available. This becomes important when the device is utilized in high-speed image display applications, either for visual or recording purposes. In such applications the relatively low current availability of the photo-cathode has been found to be inadequate.

The present invention overcomes the stated inadequacy by novel combination of means for increasing the current density of photo-cathode tubes. The invention utilizes a photo-emissive cathode similar to that described in my application Serial No. 568,236, and effects current amplification of the cathode emission to increase target response to the information to be presented.

The invention includes several embodiments and envisions the use of an assembly of large numbers of such devices or tubes in rows and columns for display board purposes. It should be clearly understood that the invention is not limited to such use, but that such use is illustrative of an application of the invention. In applications of this kind, it may be desirable to display messages by means of large size individual characters on the viewing screens of individual display tubes. It is also desirable that the characters displayed be retained on their viewing screens until selectively erased. Still another requirement in applications of this kind is to have available for display on any one tube screen a wide selection of message symbols. In character beam shaping tubes using internal beam shaping means, the practical limit built into any single envelope at present is under one hundred separate symbols. In view of the limitation of these types of tubes, and the requirements of the application referred to, the variety and quantity of symbols made available for display purposes will be under control of optical equipment external to the envelope as referred to in the related patent application. The message characters will then be projected onto the photo-emissive cathode to effect energization thereof.

It is, therefore, an object of this invention to provide a new and improved means of amplifying photo-cathode currents of a cathode ray.

It is another object of this invention to increase the current density of an information-carrying electron flow from a photo-cathode to improve the target response to the information.

It is another object of this invention to amplify electron

flow derived from a photo-cathode by modulating a second source of electrons in accordance with the cross-sectional shape of the photo-cathode currents.

It is still another object of this invention to modulate a secondary electron beam with a character shaped electron flow derived from a photo-cathode.

Objects and advantages other than those set forth will be apparent from the following description when read in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic cross-section of a cathode ray tube utilizing a photo-emissive cathode and embodying a novel amplifying means;

Figure 2 is an enlarged view in cross-section of the novel amplifying means of Figure 1;

Figure 3 is a partial cross-sectional view through the conductors of Figure 2;

Figure 4 is a diagrammatic cross-section of an additional embodiment of a cathode ray tube utilizing a photo-emissive cathode and employing another novel amplifying means;

Figure 5 is an enlarged partial view in cross-section of the electron current amplifying means of Figure 4;

Figure 6 is a partial view in elevation of the emitting surface of Figure 7;

Figure 7 is an enlarged detail view of the emitting means of Figure 4.

Shown in Figure 1 is an evacuated container **10** which may be of any desired shape and made of any desired material such as glass, plastics, metals or combinations thereof. The preferred embodiment is shown generally in the shape of a normal cathode ray tube, however, the container size and shape may be as desired and still be encompassed in the present invention.

Forming one end of the container **10** is an optically transparent window **11** which has supported on its inner surface a photo electron emissive cathode or means **12**. The photocathode **12** may be made of any known photo emissive material such as caesium, lithium, potassium, sodium, either coated on silver or like metals or directly on glass, but uses in the preferred embodiment the caesium-silver oxide type of emitter. Photo-cathode **12** may be excited by any light source external to the container (not shown, but described in Serial No. 568,236) and is capable of generating a beam of electrons or electron flow **14** in response to such excitation for projection along longitudinal axis **15**. In cooperative relation with the photo-cathode **12** there is positioned within container **10** an electron lens **13**, which may be either electrostatic or electromagnetic and is shown as electrostatic. Lens **13** directs the beam of electrons **14** emitted from the photo-cathode **12** to the surface of a stopping element or apertured electrode **16** presenting an aperture. The cathode **12** together with lens **13** form the means for generating and projecting electron flow **14**.

The instant invention improves the assembly of electron beam control elements referred to and those shown and described in my patent application Serial No. 568,236, among other improvements and advances in the art, in that a beam current amplifier unit or electron flow amplifying means **17** is placed generally adjacent the apertured electrode **16** on the side of the electrode facing the target to effect amplification of the electron flow. A first deflection system or means **18** positioned intermediate the photo-cathode means and the apertured electrode, which may be of electromagnetic or electrostatic construction is shown here as electrostatic, utilizing deflection plates **18**. Plates **18**, which may be coplanar as shown, are supplied with control voltages from control circuits **19** to effect positioning of a desired portion of the beam **14** through the aperture of electrode **16** and upon a control surface assembly **21** of the beam current amplifier **17**.

Referring to Figure 2, the amplifying means 17 is shown in greater detail and includes the control surface assembly 21. The control surface assembly 21 is comprised of an electron to light converter such as an electron-sensitive light ray generating phosphor 22, a light transparent electrical conductor layer 23, such as stannous oxide, and a photoconductive means, namely, a photoconductor layer 24, such as selenium. It should be understood that a variety of different known materials could be used for 22, 23 and 24, and such known materials are included herein. The control surface assembly 21 is supported in sandwich type construction and positioned generally coaxial with the axis 15 and transversely thereto. The phosphor 22 faces cathode 12, layer 24 faces the target, and, in between the two in contiguous relation therewith, is the conductor layer 23.

The control surface assembly 21 has positioned contiguously with the photoconductive layer 24 a plurality or assembly of conductors 29, each isolated electrically from the other by electrical insulating material 30, including such known insulators as rubber, glass, ceramics, plastics, and the like. Carried or disposed upon each of the opposite ends of the conductors 29 is a thermionic electron emissive material forming a plurality of individual or discrete thermionic emissive elements or thermionic emitters or cathodes 31. The elements 31 may be selectively connected to a negative current source through a lead 32, conducting layer 23 and conductors 29, under the control of photoconductive layer 24. The beam 14 emanating from photocathode 12, effects bombardment of the phosphor 22, which changes electron bombardment to light, and the light through transparent layer 23 selectively causes layer 24 to become conductive. The corresponding conductors then cause the thermionic emitters 31 to become excited, the negative potential from lead 32 being presented thereon. The emitter 31 is raised to an operating temperature by the transfer of heat from a heater unit 35 which is supplied with electrical energy by conductors 36 and 37. A reflector 38 may be provided to concentrate the heat generated by heater 35 on the emitters 31, thereby, improving the efficiency of heat transfer. Reflector 38 may, in addition, serve as one of the control elements of a lens system 40.

Lens system 40 may be electromagnetic or electrostatic, but is shown as electrostatic, and is used to direct the electron beam emitted by the thermionic cathode along a predetermined path within the envelope 10 generally coaxial with axis 15. A second deflection system 41 which may likewise be electromagnetic or electrostatic is shown as electrostatic, and is provided to effect control of the electron beam from emitter 31 and to direct the beam toward any desired location on a target 42. Target 42 may be supported on the inner surface of a window 43 of the envelope 10. The target 42, may be electrically responsive or may be an electron to light converter, and is shown as the latter utilizing any of the known phosphors.

In operation, a plurality of light rays, in the form of independent message symbols, as shown in U. S. 2,730,708, may be imaged on the surface of the photo-cathode 12. This may also be accomplished in accordance with the structures shown in my Serial No. 568,236. When exposed to energizing light rays, the photo-cathode 12 will provide a corresponding pattern of electron flow 14, which electron flow may be imaged on the stopping element 16 and upon control assembly 21, by means of the lens system 13. Since the electron flow 14 may contain a plurality of message symbols, deflection system 18 permits selection of a portion of the electron flow having any one of the desired symbols or a combination of such message symbols and to position that portion on the control surface assembly 21 of the amplifier unit 17. The current content of the selected portion of the electron flow 14 may then be increased, or decreased, in accordance with the design requirements of the amplifier unit 17.

In the absence of electron flow 14 to excite the phosphor 22, the passage of current from the conducting layer 23 to the emitters 31 will be zero, due to the dark resistivity of the photoconductor 24. Therefore, when the phosphor 22 is excited by the electron flow 14, the resistance of the photoconductor 24 will be lowered in accordance with the light ray pattern reaching its surface from the illuminated phosphor 22. A resultant gain in beam current is a function of the electron potential in the electron flow 14 at the time of contact with the phosphor 22. The resultant current gain or ultimate beam density may also be a function of the size of the area of control surface assembly 21 that is bombarded by electron of the electron flow 14.

The cross-sectional dimensions of the amplifying means 17 exemplified in Figures 2 and 3 may be determined by the application of the device. For example, if message symbol beams 0.010 inch ^{2}, respectively, are emitted by the photo-cathode 12 and it is desirable to have such beams appear, independently, on the surface 21 at least ten times these dimensions, then the diameter of the amplifier unit 17 would have to be large enough to accommodate a 0.1 inch ^{2} symbol. The number of conductors 29 required in an application of this kind would depend on the desired resolving power of the secondary beam emitted from cathodes 31. It is possible in this manner to identify a wide variety of message symbols utilizing a raster of 10 x 10 conductors 29.

High accelerating potentials may be administered to the electrons selected from the beam 14 by an additional anode 45, in combination with potentials applied to conducting layer 23. It may also be obvious to those skilled in the art to utilize a fine wire mesh in the case of the accelerator elements 16 and 45. Wire mesh accelerators may provide a more compact and more efficient system for energizing the phosphor 22.

A second embodiment of the invention is shown in Figure 4, wherein, the structures providing and projecting the electron flow 14 generally along the axis which are supported in one end of an envelope 20 and are generally the same as those described in connection with Figure 1, except that the aperture 46 provided in stopping plate or apertured electrode 16, is large enough only to allow a predetermined portion of the electron flow 14 to enter the remaining portion of the envelope 20 toward the target area 51, 52. In addition, this embodiment utilizes control circuits 33 as its energizing means. The target area at the other end of the envelope or tube 20 may have a face plate 50, and as shown in detail in Figure 5, may also have a target or phosphor screen 51 disposed thereon, with a metallized backing 52, such as aluminum, disposed on target 51.

Positioned generally adjacent the target, and, in spaced relation therewith, is a storage means. The storage means comprises generally an electrostatically chargeable storage mesh 53 spaced from backing 52, a collector screen 54 spaced from mesh 53, a beam intensifier 57, a barrier mesh 58, each spaced from the other and disposed in a sandwich like construction generally coaxially disposed about the axis in the order stated from target toward cathode. Positioned adjacent the apertured electrode 16 and facing the target is a thermionic emitter 60, similar in emitting materials to be used for emitters 31, namely, known emitting materials including thorium oxide, barium oxides and the like, and capable of generating and projecting an electron beam 64 generally coaxial with the axis. In order to position emitter 60 substantially coaxially with the axis 15, it may be made annular in shape and placed adjacent and about the aperture 46 as shown in detail in Figures 6 and 7. Intermediate the emitter 60 and the storage means is disposed, generally coaxially with the axis, an electron lens. The electron lens, as is well known in the art, may be electromagnetic or electrostatic, but for purpose of illustration is shown as an electrostatic lens **56**.

The cathode ray apparatus of Figures 4 and 5 may be used in combination with an input information light source and system control means similar to that shown in my application Serial No. 568,236 as aforestated. The instant apparatus may be used in display systems wherein large message symbols may be displayed singularly on the viewing screen **51** and retained for continued viewing by utilization of electrostatic charges on the storage mesh **53** created thereon in response to excitation to the selected portion **14***a* of electron flow **14**. An individual character shaped beam or portion **14***a* may be selected from a plurality of such beams in the electron flow **14** generated by the photo-cathode **12**. The selection of the portion **14***a* through the aperture **46** allows it to be directed toward the viewing screen **51** through lens system **56** which not only lenses the cross section, effecting desired cross over, on axis, on both portion **14***a* and electron beam **64**, but also increases the velocity of the electrons and expands the cross-sectional area of the beam or portion **14***a* sufficiently to meet the size requirements of the finely displayed image on the screen **51**.

Immediately in front of the screen **51** and metallized backing **52** toward the cathode **12** is the storage means or memory screen system including the heretofore enumerated fine wire mesh **53** coated with insulating target elements **63** and fine wire mesh collector screen **54**. This general assembly of elements is old in the art of cathode ray storage tubes which utilize a writing beam and a reading beam. In the present invention the writing beam **14***a* is derived from primary beams or electron flow **14**, and the reading beam or electron beam **64** is derived from the thermionic cathode emitter **60**. The cathode **60** shown in detail in Figures 6 and 7 may include a metallic cup **70**, a heater element **71** and the stated oxide coated surface **72**. Electrical energy is supplied to the heater element **71** through a pair of conductor leads **80** and **81**. A plan view of the cathode surface **72** is shown in Figure 6. The outside diameter, for example, may be approximately 0.1 inch and the center opening **86** about 0.02 inch. In this embodiment, for simplicity of illustration, it is advantageous to generate and control the writing and reading beam **14***a* and **64**, respectively, about the common optical axis **15** of the tube **20**. The cathode assembly **60**, therefore, is supported coaxially with the optical axis **15** and is provided with opening **86** through the center of the cathode. The opening **86** as stated heretofore is aligned to encompass and aid the aperture **46** in selecting and permitting passage of a character shaped beam **14***a* therethrough and is coaxial with the axis **15**.

Under ordinary circumstances the current density of character shaped beam **14***a* would be insufficient to energize the phosphor **51** to the desired light levels primarily due to the relatively low level electron emission capabilities of photo-cathodes, and secondly because it may be desired to expand the initial individual character beam size from approximately 0.010 inch^2, at the time it leaves the photo-cathode **12**, to perhaps 100 times this dimension when displayed on the screen **51**. Through the use of a high potential, low current beam **14***a*, a control charge pattern may be applied to the surface material **63** of the grid **53** and which in turn controls the passage of the much slower, but higher density, electrons of the reading beam **64**.

When a writing pulse is applied to photo-cathode **12** through a capacitor **90** from pulse generator **91**, a pulse is also applied to the intensifier **57** through a capacitor **92**. After the low current beam **14***a* passes through the barrier mesh **58** and comes under the influence of the intensifier **57**, the beam **14***a* potential will have attained the level necessary to induce conductivity in the surface material **63**, and further produces secondary emission upon being subjected to bombardment by the high energy incident electrons.

The surface material **63**, such as talc or other known materials, is a dielectric material having a high specific resistance. Induced conductivity, on the other hand, is brought about because of the matrix structure of solid material. The molecules composing the material form a matrix structure which occupies only a small fraction of its apparent volume. When bombarded by high energy electrons, large numbers of electrons are freed from their molecular bonds to constitute electrons raised to the conduction band energy level. By means of a suitable potential gradient between the dielectric material **63** and the collector mesh **54** the freed electrons are attracted through the molecular matrix of the material **63** and toward the collector mesh **54**.

Under the influence of potentials applied to the lens system **56**, electrons emitted from the surface **72** of the cathode **60** are directed uniformly over the entire storage surface **63**, of the grid structure **53**, thereby developing a visible image of the charged pattern on the storage mesh **53**.

The theory of operation and an example of the operating parameters of the storage means necessary in the performance of the memory system included in this display device will be found in a published book by John Wiley & Sons, Inc., New York, N. Y., entitled "Storage Tubes and Their Basic Principles," authored by M. Knoll and B. Kazan. The operation of the control elements selected for the present tube application is described on pages 78 through 81 of the above book.

The particular embodiment of the invention illustrated and described herein is illustrative only and the invention includes such other modifications and equivalents as may readily appear to those skilled in the art, within the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In an evacuated container comprising photo-cathode means positioned at one end thereof for generating and projecting electron flow, a target at the other end capable of responding to electrons, amplifying means interposed in the path of and generally coaxially with the electron flow intermediate the target and the photo-cathode means for effecting amplification of the electron flow, said amplifying means including a thermionic emitter capable of producing an electron beam on a path coaxial with the electron flow, means responding to the electron flow for modulating the electron beam of the emitter.

2. In an evacuated container comprising photo-cathode means positioned at one end thereof for generating and projecting electron flow, a target at the other end capable of responding to electrons, an apertured electrode disposed in the path of the electron flow for selectively limiting the cross section of the electron flow therethrough, amplifying means interposed in the path of the electron flow intermediate the apertured electrode and the target for effecting amplification of the electron flow, said amplifying means including a thermionic emitter capable of producing an electron beam, means responding to the electron flow for modulating the electron beam of the emitter.

3. In an evacuated container having a longitudinal axis comprising photo-cathode means positioned at one end thereof for generating and projecting electron flow along said axis, a target at the other end capable of responding to electrons, amplifying means interposed in the path of the electron flow intermediate the target and the photo-cathode means for effecting amplification of the electron flow, said amplifying means including a thermionic emitter capable of producing an electron beam, said emitter being disposed coaxially with said axis, means responding to the electron flow for modulating the electron beam of the emitter.

4. In an evacuated container having a target at one

end thereo fand a photo-cathode means capable of generating an electron flow at the other end thereof, and utilizing therebetween a first deflection means, an apertured electrode presenting an aperture, said electrode being positioned intermediate the first deflection means and the target, said first deflection means being capable of deflecting the beam to position a desired portion thereof through said aperture of said apertured electrode, the improvement comprising means adjacent said apertured electrode and positioned intermediate said apertured electrode and said target, said means including an electron-to-light converter positioned in the path of and responsive to excitation by said electron flow, a light transparent conductor positioned contiguous said converter and intermediate it and the target, and a photoconductive means positioned contiguous the opposing surface of said conductor, a plurality of mutually insulated conductors having one extremity thereof positioned contiguous the free surface of said photoconductive means, discrete thermionic emissive elements disposed upon the opposing extremity of said conductors, and a heating means positioned adjacent said thermionic emitting elements for heating said thermionic emissive elements.

5. The invention of claim 4 wherein the means adjacent the apertured electrode is positioned transversely across the electron flow and parallel to the apertured electrode, said means further having a cross-sectional area at least as great as the aperture.

6. In an evacuated container having a target at one end thereof and a photo-cathode means capable of generating an electron flow at the other end thereof, and utilizing therebetween a first deflection means, an apertured electrode presenting an aperture, said electrode being, positioned intermediate the first deflection means and the target, said first deflection means being capable of deflecting the beam to position a desired portion thereof through said aperture of said apertured electrode, the improvement comprising means intermediate the electrode and the target for amplifying the electron flow, said means including an annular thermionic emitter capable of electron beam generation, said emitter being adapted to permit passage of electron flow therethrough, a lensing means and a storage means both positioned intermediate the emitter and the target, the lensing means being adjacent the emitter and being adapted to cause appropriate lensing action and cross over of each the electron flow and the electron beam, said storage means being capable of responding to store the response of said electron flow thereon, and said electron beam being capable of shadowing said stored response onto said target.

7. The invention of claim 6 wherein the electron flow is projected generally along the longitudinal axis of the container and the apertured electrode and the means for amplifying the electron flow are all positioned coaxially with respect to the longitudinal axis.

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