May 16, 1967 HIDEKI KOBAYASHI 3,320,458

CATHODE RAY TUBES EMPLOYING A NOVEL CONVERGENT ELECTROSTATIC LENS SYSTEM FOR BEAM MODULATION

Filed Jan. 4, 1963

2 Sheets-Sheet 1

FIG. 1.

PRIOR ART

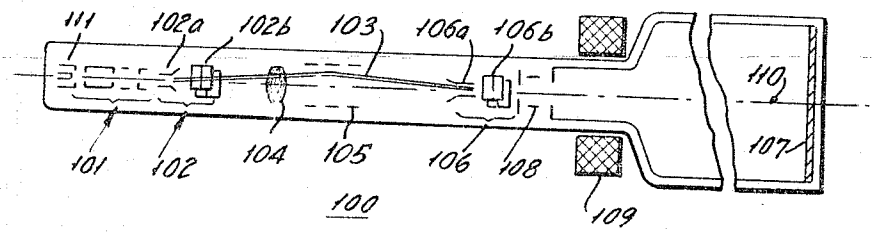


FIG. 2A.

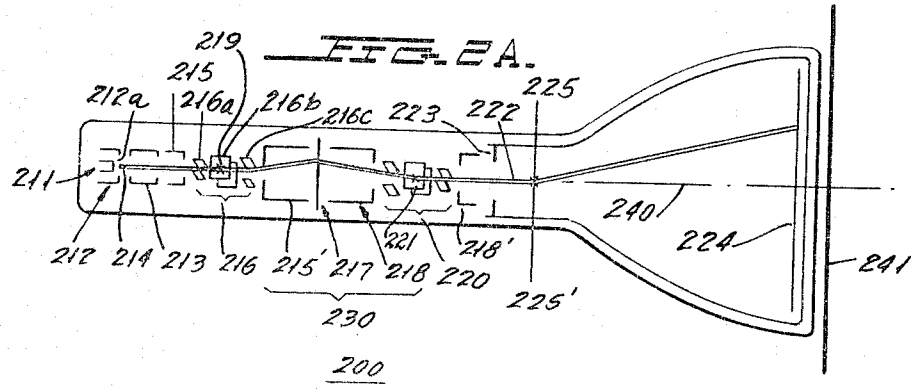


FIG. 6A.

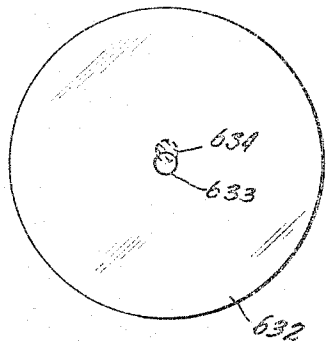
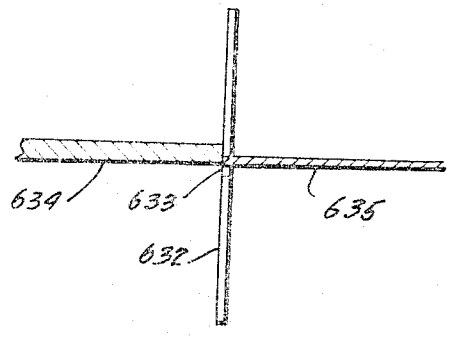


FIG. 6B.



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Filed Jan. 4, 1963 2 Sheets-Sheet 2

FIG. 2B.

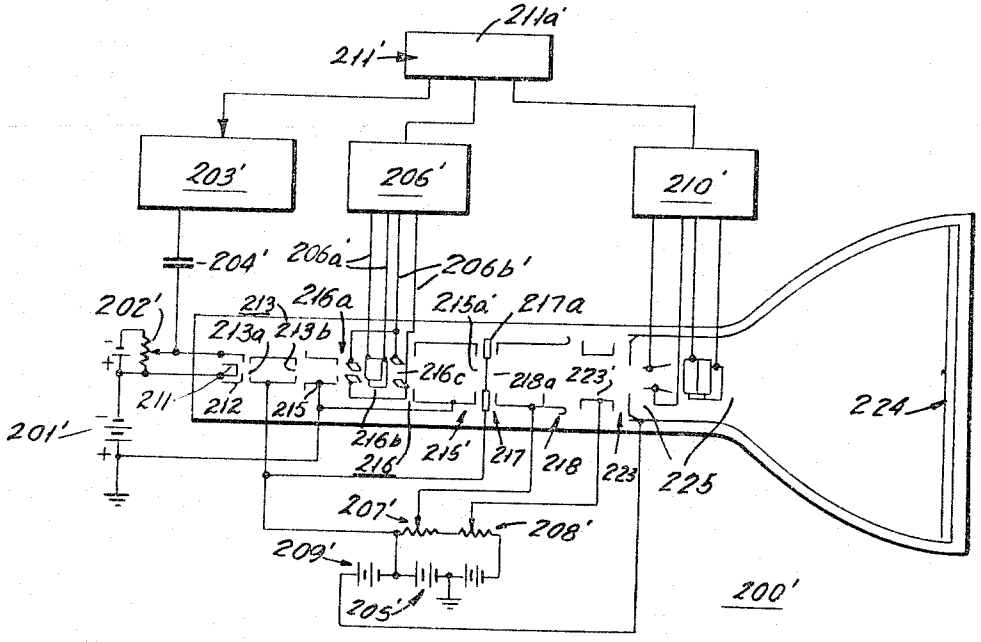


FIG. 3A.

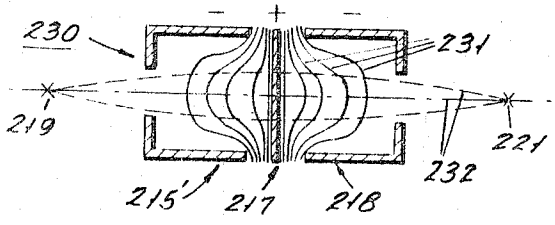
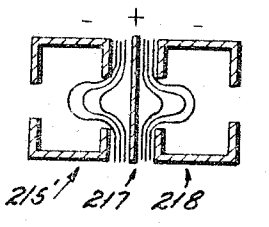
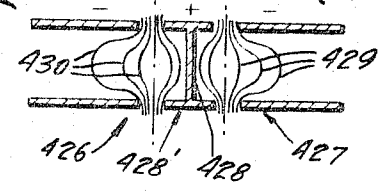


FIG. 3B.



400

FIG. 4A. (PRIOR ART)



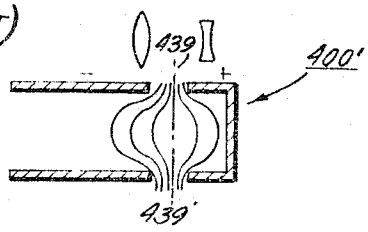


FIG. 4B.

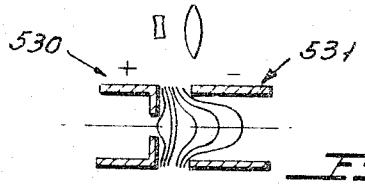


FIG. 5.

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CATHODE RAY TUBES EMPLOYING A NOVEL CONVERGENT ELECTROSTATIC LENS SYSTEM FOR BEAM MODULATION

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Claims priority, application Japan, Jan. 18, 1962, 37/1,803
3 Claims. (Cl. 313—86)

This invention relates to cathode ray tubes and more particularly to a novel lens system for cathode ray tubes, particularly of the character reproducing type which provide either recorded or visual displays of predetermined characters.

Among various types of cathode ray tubes that have been employed for producing character shaped electron beams, two kinds of tubes registered under the trademarks of "Charactron" and "Typotron" have been shown to be two of the most effective embodiments as far as the production of character shaped beams having high efficiency and high brightness. Such tubes are normally comprised of electron gun means for producing an electron beam, means for accelerating the electron beam, deflection means for controlling the impingement of the electron beam upon a character matrix, electron lens means for converging or restoring the electron beam to the cathode ray tube central axis and second deflection means for controlling the location of the character shaped electron beam upon the cathode ray tube fluorescent surface positioned at the face of the electron tube. Such configurations impose substantially large space requirements for the employment of such character forming cathode ray tubes. The converging means employed in such prior art devices requires a fairly long converging space in order to restore the electron beam to the cathode ray tube central axis. This one feature causes the overall size of such character display cathode ray tubes to be so bulky as to become an impediment for reduction in size of the systems in which such tubes are employed.

The instant invention provides a novel all converging and hence non-diverging lens system which provides the sensitivity at least equal to such prior art devices, while at the same time imposing substantially smaller space requirements upon the lens system thereby enabling the production of a character-display cathode ray tube which is substantially shorter in length than prior art devices. While such an arrangement lends itself ready to character-display cathode ray tubes, it has been found that this lens system has advantageous application in regular cathode ray tubes in which a substantially circular shaped electron beam impinges upon the face of the cathode ray tube.

The device of the instant invention includes basically all of the elements of the prior art devices and in addition thereto, a novel converging lens system which is comprised of three electrode elements. The first electrode element incorporates the character matrix which is employed to form predetermined characters in accordance with the shapes of the openings provided in the character matrix. The second electrode is positioned between the cathode ray tube electron gun and the first electrode and immediately adjacent the first electrode, while the third electrode is positioned immediately adjacent the first electrode and between the first electrode and the face of the cathode ray tube. The first electrode is substantially planar in shape and is positioned substantially on the planar equipotential surface located between the second and third electrodes. The potential

of the first electrode is made more positive relative to the second and third electrodes in order to form a converging electrostatic field pattern lens. It has been found that with this arrangement the second and third electrode members can be made substantially shorter than prior art devices and the first electrode member being substantially planar in shape is likewise substantially shorter than prior art electrodes so that the overall length of the three electrode lens system is substantially shorter than prior art lens systems employed to perform substantially the same functions. Positioning of the first electrode along the planar equipotential line permits the use of lower potential differences which are imposed upon the three electrodes with no accompanying decrease in sensitivity of the system. In addition thereto, the shaped electron beam does not undergo any divergence thereby enabling the shaped beam to be more accurately positioned upon the face of the cathode ray tube.

It is therefore one object of the instant invention to provide a novel lens system for cathode ray tubes thereby enabling the overall length of such cathode ray tubes to be substantially diminished.

Another object of the instant invention is to provide a novel lens system for cathode ray tubes wherein the electron beam passing through the lens system experiences no divergent forces.

Another object of the instant invention is to provide a novel three electrode lens system wherein the matrix electrode is positioned substantially in alignment with the planar equipotential surface of the equipotential field pattern generated by the three electrode lens system.

Still another object of the instant invention is to provide a novel lens system for cathode ray tube structures comprised of three electrodes wherein the central electrode of the three electrode system is substantially a flat plate-shaped member positioned on the planar equipotential surface of the equipotential field pattern generated by the three electrode lens system.

Another object of the instant invention is to provide a novel electrostatic lens system for cathode ray tubes to provide for electron beam modulation.

Still another object of the instant invention is to provide a novel control grid for cathode ray tubes.

These and other objects of the instant invention will become apparent when reading the accompanying description and drawings in which:

FIGURE 1 shows a longitudinal cross-sectional view of a conventional character-display cathode ray tube.

FIGURES 2*a* and 2*b* show longitudinal cross-sectional views of two alternative embodiments of character-display cathode ray tubes designed in accordance with the principles of the instant invention, wherein FIGURE 2*b* further shows in block diagram form the control elements for operating the cathode ray tube.

FIGURES 3*a* and 3*b* show two alternative embodiments for the lens systems employed in the cathode ray tubes of FIGURES 2*a* and 2*b* respectively, and further show the equipotential lines of the electrostatic field pattern produced by the lens systems.

FIGURES 4*a* and 4*b* show embodiments of electron lens devices employed in conventional character-display cathode ray tubes and further showing the equipotential lines of the field patterns generated by the electron lenses.

FIGURE 5 shows the focusing lens system employed in the embodiments of FIGURES 2*a* and 2*b* employed for producing an electron beam with a fixed cross-sectional area.

FIGURE 6*a* shows a plan view for an embodiment of a matrix mask used in electron gun designed in accordance with the principles of the instant invention useful in

applications where it is desired to modulate the intensity of an electron beam.

FIGURE 6*b* shows a side view of the matrix mask of FIGURE 6*a* further showing the intensity modulation experienced by the electron beam passing therethrough.

Referring now to the drawings, FIGURE 1 shows a conventional character-display cathode ray tube **100** which is comprised of an electron gun **111** which is suitably operated to generate an electron beam. The electron beam **103** moves along the longitudinal axis **110** of the cathode ray tube **100** from the electron gun **111** towards the face **107** of cathode ray tube **100**. Moving in this direction, the electron beam first passes through an electron lens system **101** which is employed for the purpose of shaping the electron beam in order that it have a predetermined diameter. The beam is then passed through first and second pairs of deflection plates or character selection plates **102** wherein deflection plate pair **102***a* is suitably controlled to deflect the electron beam in the vertical direction (up or down) while the deflection plate pair **102***b* deflects the electron beam in the horizontal direction (to the right or to the left) so as to cause the electron beam to deflect in two mutually orthogonal directions. Thus it can be seen that the electron beam **103**, after it leaves the deflecting plate pairs **102** moves to a position away from the longitudinal axis **110**. Electron beam **103**, having been suitably accelerated, moves to the right and passes through an apertured matrix element **104** which is disposed so as to be perpendicular to the central axis **110** of the rotationally symmetrical electron gun. The matrix is usually in the form of a thin metallic circular mask having a plurality of apertures each being of a different configuration. The configurations of the openings are formed so as to represent alpha-numeric characters such as the alphabet letters A through Z and the decimal characters 0 through 9 and any other suitable symbols. Thus, the electron beam in passing through one of the apertures takes on the shape of the opening through which it passes and its cross-section thereby resembles an alpha-numeric character. The openings or apertures in the matrix **104** may be positioned in the regular order of rows and columns or in any other suitable arrangement. By controlling the deflection of the electron beam by the deflection plate pairs **102** this controls the electron beam to impinge upon only one of the group of apertures in the matrix element **104**. It can be readily understood therefore that the control voltages imposed upon the deflection plate pairs **102** are thereby employed for the purpose of selecting the alpha-numeric character which is to be generated on the face **107** of the cathode ray tube structure **100**.

It is then necessary to cause the electron beam **103** to return to the longitudinal axis **110** of the cathode ray tube so that it may then be controlled in order to be positioned on any desired location on the face **107** of cathode ray tube **100**. For this purpose, a converging device **105** is employed to restore the electron beam **103** to the central axis **110**. The beam under control of the converging device **105** returns to the longitudinal axis **110** and is then subjected to the control of a third and fourth pair of electrostatic deflection plates or character compensating plates **106** wherein the deflection plate pair **106***a* is employed to move the electron beam in the vertical direction while the deflection plate pair **106***b* is employed to move the electron beam **103** in the horizontal direction. The electron lens system **108** is provided for the purpose of controlling the diameter of the shaped electron beam while the electromagnetic deflection system **109** which is comprised of an energized coil is employed for the purpose of deflecting the shaped electron beam **103** on to a desired position or location of the screen or face **107**.

The electron gun elements **101–111** and the character selection plate pairs **102** in the character-display cathode ray tube **100** are of substantially the same dimension as such elements employed in general purpose cathode ray tubes. However, the converging device for lens system **105** requires a substantially long converging space in order to restore the electron beam which is accelerated by a potential of several thousand volts and deviated from the central axis by a deflection voltage of the order of tens of volts or more so as to return to the central axis. In addition thereto, the deflection system **109** and lens system **108** are likewise appreciably large. These dimensions thus result in a character-display cathode ray tube whose overall size is so large and bulky as to become an impediment to attempts to reduce the size of equipment in which such cathode ray tubes are used.

The instant invention has as a primary objective the provision of a novel electron beam shaping arrangement in which the length of each of the elements of the cathode ray tube, namely, the electron gun, the character selection plates, the compensating plates, the converging device and the converging space are substantially contracted. Coupled with these improvements, the distance from the character matrix to the electron lens system, as well as the distance from the electron lens system to the screen is also substantially contracted enabling characters to be projected with the same magnification factor as in prior art devices. Thus the character display cathode ray tube with the novel arrangement of the instant invention can be constructed to have a much shorter overall length as compared with such conventional devices.

Another object of the instant invention is that of decreasing the deflection control voltage levels required for the character-display cathode ray tube. In the character-display cathode ray tube of the instant invention, both the character selection plates and the compensating plates perform their functions by being fixed in positions through which an electron beam passes at a comparatively low velocity thereby enabling control of the electron beam for character selection and compensation to be performed by the use of extremely small deflecting electric field magnitudes as compared with conventional cathode ray tubes. Such an arrangement lends itself readily to the employment of all-transistor driving circuits which inherently operate at much lower voltage levels.

Still another important object and likewise advantage of the instant invention is to provide the character display cathode ray tube with an electron gun arrangement capable of controlling the intensity of an electron beam current flowing towards the screen by a comparatively low control voltage when the arrangement of the instant invention is employed in general purpose cathode ray tube structures. Employment of such an electron gun configuration in television-picture tubes, for example, would permit the entire transistorization of a video signal amplifier circuit.

When employed in general purpose cathode ray tube structures the matrix is designed to have a single aperture of suitable configuration in lieu of a plurality of character forming apertures whereby the size of a single aperture is of the same order as the cross-sectional area of an electron beam that passes therethrough. By deflection of the cathode ray beam by the character selection plates the beam current passing through the aperture may be controlled in order that the intensity of the beam current arriving at the screen may be modulated. Hence, suitable modulation or gamma characteristics of the electron gun may be selected by the configuration of the aperture provided in the matrix.

One preferred embodiment **200** of the cathode ray equipment designed in accordance with the principles of the instant invention is shown in FIGURE 2*a*. It should be understood that only parts necessary for the description of the instant invention have been illustrated and hence the control means for the deflection system and other electrodes which are not directly necessary for understanding the description of the device have been omitted for purposes of clarity.

In the embodiment **200** of FIGURE 2*a*, electrons are

emitted from the cathode **211** which is operated at a zero or reference potential and a "cross over" **214** is formed by a control grid **212** having an aperture **212***a* which control grid operates normally at a negative potential relative to the cathode and which crossover is further formed by the accelerating grid **213** which operates at a positive potential of the order of several hundred volts relative the cathode. In order to obtain an electron beam of fixed cross-sectional area, a focusing electric field pattern is established in the proximity of the area between the accelerating grid **213** and a first low-voltage electrode **215** which is at a lower potential level. Thus, the electron beam **222** emerges from the electrodes **212**, **213** and **215** as a focused electron beam of fixed diameter and hence, fixed cross-sectional area.

The electron beam is caused to be deflected in two mutually orthogonal directions by means of character selection assembly **216** comprising three pairs of deflection plates **216***a*–**216***c*. Deflection plate pairs **216***a* and **216***c* serve to deflect the electron beam **222** in a vertical direction (up or down) while deflection plate pair **216***b* serves to deflect the electron beam **222** in a horizontal direction (left or right). The average potential of the deflection plate system is approximately equal to that of the first low-voltage electrode **215** and a second low-voltage electrode **215'**. The use of three sets of deflection plates as shown in FIGURE 2*a* is advantageous to the coincidence of the location of the vertical and horizontal deflection centers **219**. But this arrangement is by no means an indispensable one and any other type of deflection system used is conventional cathode ray tube structures may be adapted for use in the cathode ray structure of the instant invention. For example, it is possible to use an arrangement having two sets of deflection plates. It is difficult, however, in such arrangements to make the deflection centers coincident such as is possible in arrangements using three sets of deflection plate pairs.

After passing through the deflection system the electron beam **222** is caused to impinge upon and hence pass through one of the character forming apertures provided in the matrix **217** thus causing a shaped electron beam having the configuration of the aperture upon which it passes through to be emerged through matrix **217**. The matrix **217** is maintained at a voltage which is at a higher potential level with respect to the potential of the first low voltage electrode **215'** and a second low voltage electrode **218**. This causes an intensely convergent potential distribution to be formed in this region which is illustrated in FIGURE 3*a* wherein the lens system **230** of FIGURE 2*a* has been reproduced as shown in FIGURE 3*a*. Thus the three electrode system comprised of the low-voltage electrode **215'**, the matrix **217** and the low-voltage electrode **218** causes electrons emerging from the deflection center **219** of the character selection plates to be focused at the deflection center **221** of the compensating plates **220**, to be more fully described.

In FIGURE 3*a* the cross-hatched elements shows a longitudinal cross-sectional view of the three electrode system **230** with the solid curve lines **231** denoting the equipotential lines of the electrostatic field pattern generated by the lens system **230** which is caused by the voltage biasing arrangement whereby the center or matrix electrode **217** is at a higher potential than the electrodes **215'** and **218**. The dashed lines **232** denote the manner in which the electrons emerging from the deflection center point **219** converge at the second deflection center **221**. This converging action, as will be described subsequently in more detail, is so intense that the equivalent action can take place with the potential difference of these electrodes being about $\frac{1}{10}$ the level of the potentials employed in conventional three-electrode electrostatic lens systems. At the same time, the length between each deflection center **219** and **221** can be appreciably diminished. Furthermore, as there is no need to lower the potentials of the first and second low voltage electrodes **215'** and **218** to the same order of the potential at cathode **211** the electron beam **222** can thus be progressed at a suitable velocity in the vicinity of the first and second low voltage electrodes **215** and **215'** and **218** and **218'** as well as the character selection plate arrangement **216** and **220**.

The shaped electron beam **222** which emerges from the matrix **217** and undergoes a convergence so as to be redirected in order to return to the longitudinal axis **240** of the cathode ray tube **200** is further controlled by the three deflection plate pair system **220** to maintain its movement along the longitudinal axis **240**. The shaped electron beam **222** then undergoes electron lens action such as is developed between the second low voltage electrode **218'** and the post acceleration electrode **223**, which is maintained at a high potential relative to the cathode in order to focus an image of the character selected from the matrix upon the target **224** which causes the luminescent film of which the target **224** is formed to radiate photons in the configuration of said character or in the alternative, to set up a charge pattern which may be stored on suitable storage film (not shown) which is positioned adjacent the target. The electron lens system formed by the second low-voltage electrode **218'** and the post acceleration electrode **223** may be provided with an additional electrode (not shown) for adjusting the lens action disposed therebetween. This arrangement provides a convenient means for varying to a certain extent the size of an image projected on the target **224**. Although a deflection system for varying the position upon the target **224** upon which the shaped electron beam strikes is not indicated in FIGURE 2*a*, it should be understood that such deflection may be provided by either the use of two sets of electrostatic deflection plates or two sets of electromagnetic coils which should be installed in the vicinity of the vertical line **225**–**225'** in order to provide a suitable deflection system for the character display cathode ray tube **200**.

One practical embodiment which has been constructed employed a matrix having ten numerals, the twenty-six letters of the Arabic alphabet, forty-eight Japanese Kana letters and twelve miscellaneous symbols, thus providing a total of ninety-six characters which were perforated in a matrix mask using a photoetching technique. A group of characters generally comprised of both alphabetic and numeric characters are commonly referred to as alphameric characters, and will henceforth be referred to by the term alphameric characters. Any suitable metal may be used for forming the matrix mask providing photoetching can be successfully performed upon the metal selected. A nickel or copper alloy of approximately twenty microns in thickness has been found to provide favorable results. Pure copper was employed and it was found to be too soft but upon addition of several percent of beryllium to pure copper it was found that the resulting composition provided very favorable results. By finishing the alloy surface by means of rhodium plating it was found that the emission of secondary electrons and deterioration of the metal due to bombardment of electrons was significantly reduced.

In accordance with the aforementioned exemplary embodiment the width of the line of the character forming aperture in the matrix is less than twenty microns and each character forming aperture has a height of approximately 0.4 millimeter. The spacing between two adjacent character forming apertures was chosen to be approximately one millimeter. Therefore, the disturbance of an electric field near the matrix owing to the character forming apertures is of such order as to not deleteriously effect the converging action of the three electrode lens system **230** and the picture quality of the projected characters upon the target **224** was found to be excellent.

Where the character forming apertures are disposed near the center region of the matrix **217**, in a case, such as, for example, where the number of characters employed

is comparatively small and hence the deflection of the electron beam need not be too great, then the construction of both the first and second low voltage electrodes **218** and **218'** are chosen to be of the apertured disc type, as shown in FIGURE 3*b*, as opposed to the cylindrical type, as shown in FIGURE 3*a*, in order to enhance the strength of convergence of the electron lens system. Thus the deviation of the electron beam from the central axis **240** can be greatly minimized with the result that the compensating deflection plate system **220** can either be dispensed wth altogether, or in the alternative, the electron lens system **218'** employed for the projection of an electron beam to the target, can be positioned to be much closer to the matrix plate. An embodiment employing this arrangement is illustrated in FIGURE 2*b*, to be more fully described.

FIGURE 2*b* shows a character display cathode ray tube assembly **200'** wherein like elements are designated by like numerals, as between FIGURES 2*a* and 2*b*. In accordance with the embodiment **200'** of FIGURE 2*b*, the first low-voltage electrodes **215** and **215'** are connected to ground, or reference potential while a negative voltage of approximately 600 volts is applied to cathode electrode element from power source **201'**. A negative bias of 100 volts at maximum with respect to cathode electrode **211** is applied to control grid **212** from terminal **202'** provided on a variable voltage divider while a gating signal for the electron beam is transmitted from an unblanking pulse generator **203'** connected to electrode **212** via a suitable capacitor element **204'**.

Both the accelerating grid **213** and the matrix electrode **217** are maintained at a positive potential of approximately 2,500 volts with respect to ground by means of a power source **205'**. The character selection deflection plate system **216** receives the deflection voltages for character selection from the character selection voltage generator **206'**, the average potential of which is ground potential. Output terminal pair **206***a'* of generator **206'** is employed for the purpose of controlling the horizontal deflection plates **216***b* while output terminal pair **206***b'* is employed for the purpose of controlling the vertical deflection plate pairs **216***a* and **216***c*.

The second low voltage electrode **218** and the auxiliary electrode **223'** employed to adjust the electron lens action are respectively connected to variable voltage terminals **207'** and **208'** so that the two voltages applied are in the range from −600 volts to −2500 volts relative to ground in order to fit an appropriate size character at a definite position upon the target **224** of the cathode ray assembly **200'**. The post-acceleration electrode **223** is maintained at a positive potential of 5500 volts relative to ground by means of power source **209'** and **205'** while a signal is applied to the deflection system **225** from the position selection voltage generator circuit **210'**. The unblanking pulse generator **203'** and the character and position selection voltage generators **206'** and **210'** are all controlled by the input signal **211'** which is impressed upon a control circuit **211***a'* utilized to control circuits **203'**, **206'** and **210'**.

A typical example of the dimensions of the principal electrodes of the embodiment of FIGURE 2*b* is as follows:

The diameters of the electrodes **213**, **215**, **215'** and **218** are respectively 13 mm., 13 mm., 38 mm. and 38 mm. The lengths of these electrodes are respectively 25, 15, 34, and 40 mm. The diameter of the aperture provided on each side of the acceleration grid **213**, such as the apertures **213***a* and **213***b* is 2 mm. The diameter of the apertures **215***a'* and second low-voltage electrodes **215'** and **218** respectively, is 18 mm. The matrix **217** is a flat disc 20 microns in thickness and 25 mm. in diameter. The matrix is fitted between two metallic rings **217***a* positioned on opposite sides of the matrix plate **217** wherein said rings have an outer diameter of 42 mm., an inner diameter of 18 mm. and are each 0.5 mm. in thickness, giving it an overall thickness of 1.0 mm. The inner diameter and length of the electrode **223'** are both 25 mm., while the inner diameter of electrode **223** is 18 mm. The spacing between electrodes **213** and **215** is 3 mm.; the spacing between electrodes **215'** and **217** and that between **218** and **217** are both 3 mm., while the spacing between electrodes **218** and **223'** is 4 mm., and the spacing between electrodes **223'** and **223** is 10 mm. The first low-voltage electrodes **215** and **215'** are spaced apart by 61 mm. In the case of the embodiment **200** of FIGURE 2*a*, it is necessary only to apply a waveform proportional to the voltage applied to the character selection plates **216** to the compensating plate system **220**, with the mutual relations among voltages to be applied to the other electrodes being essentially the same as those described for the electrodes of FIGURE 2*b*.

In conventional character display cathode ray tubes it is customary to install a large convergence coil (not shown) disposed externally of the cathode ray tube envelope with the matrix being positioned in the middle of said coil, that is, being positioned intermediate the ends of said coil, or in the alternative, providing an external convergence coil or a converging three electrode lens system, such as the lens system **105** of FIGURE 1 which is positioned on the screen side of the matrix element **104**. There are physical limitations as the size of each of the character forming apertures in the matrix as well as the clearance between two adjacent apertures due to the fact that the electron beam cannot be made any thinner than a prescribed value due to the inherent bunching limitations of an electron beam which has been described in detail in publications, texts and technical journals. In the case employing a three electrode converging lens system, such as the lens system **105** of FIGURE 1, the electron beam **103**, after passing through the matrix, undergoes the converging action while progressing in its movement in the direction of the target, with a deflection being imposed upon it by the character selection plate system **102**. In such a case, when the electron beam **103** reaches the converging lens system **105** a deviation of the beam from the central axis of the eletcron gun becomes relatively large. The spherical aberration effect of the converging lens system **105** becomes quite predominant and therefore the directional compensation becomes quite imperfect and the rate of variation in position on the target, depending upon which character is selected, becomes rather large. It is a desirable condition, therefore that the plane of the matrix comprise a central plane of the convergence system to maximize the deviation of the electron beam deflected by the character selections plates from the central axis of the electron gun at a position at which the electron beam strikes upon the matrix. It is difficult, however, to achieve this condition with a conventional single unipotential type electrostatic lens. This could be accomplished by installing either an external convergence coil or a unipotential type of electrostatic lens on each side of the matrix, or by using a construction, as shown in U.S. Patent No. 2,986,669 entitled Electrostatic Lens Arrangement for Cathode Ray Tubes, issued May 30, 1961 to N. J. Koda.

If a convergence coil is employed to overcome these disadavantages, it has been found that the effective region of the converging magnetic field expands on the one hand and a direct current for energizing the coil is necessitated on the other hand. According to the Koda patent the comparatively short electron lens assembly **400**, shown in FIGURE 4*a*, consists of two cylindrical electrodes **426** and **427** and a short cylinder **428'** for supporting the matrix **428**. The first and second electron lenses are formed respectively between the electrodes **426** and **428** and between the electrodes **427** and **428** in such a manner that they are symmetrically disposed with respect to

the matrix as shown by the equipotential lines **430** and **429** respectively. However, the construction of FIGURE *4a* still fails to overcome the fact that a general electrostatic lens is a compound convergence lens incorporating a convergent region and a divergent region. In other words, some divergent region, or some extra non-convergent region is still retained in such a construction.

In accordance with the instant invention, the matrix is positioned so as to coincide with a planar equipotential surface at the center of an electrostatic lens and by the positioning of the matrix in the equipotential plane, such as, for example, the equipotential plane **439–439'** shown in the left side lens assembly **400'** of FIGURE *4b*, or a two-apertured disc electron lens, the divergent region of the right side of phantom line **439, 439'**, that would otherwise be existent, can be extinguished and converted to a convergent electric field similar to that in the left side region, reinforcing the convergent action and at the same time consolidating in the vicinity of the matrix the converging range of both electron lenses that have been existing apart on opposite sides of the matrix by removing the divergent or non-convergent region between these lenses, whereby the contraction of the distance between the character selection plates and the conpensating plates may readily be accomplished.

According to the embodiments of the instant invention, as shown in FIGURES *2a* and *2b*, an electron lens provided with a substantially purely convergent property, as shown in FIGURE *5*, is employed for the electron gun element in order to produce an electron beam with a fixed cross-sectional area, thus providing the electron gun structure with an additional advantageous feature. In FIGURE *5*, element **530** denotes the accelerating grid while element **531** denotes the first low-voltage electrode. In FIGURES *3a* and *3b*, *4a* and *4b* and *5*, the plus sign (+) denotes electrodes on which comparatively higher potentials are imposed and the minus sign (—) denotes electrodes on which comparatively low potentials are imposed, while the hatched portions denote cross-sections of electrodes cut with a plane which contains a central axis of said electrodes which are locationally symmetric about the central axis and the solid lines shown therein denote the lines of intersection between the equipotential surfaces and the plane which contains the central axis.

Thus it can be seen that by employing the character forming matrix, such as the matrices **217**, shown in FIGURES *2a* and *2b*, as one of the convergent electron lens elements, the characteristics of the electron lens of the present invention is capable of providing an intense convergent action within a short axial length, as compared with conventional lens systems, such that the arrangement solves a number of difficult problems encountered in conventional shape beam generating electron guns, while realizing still further the advantages of reducing both the potentials applied to the electrodes of the cathode ray structure, as well as the control voltages, and the contraction of overall length of the character display cathode ray tubes, such as, for example, the tubes **200** and **200'** shown in FIGURES *2a* and *2b* respectively.

FIGURES *6a* and *6b* show front and side views respectively, of a single-apertured matrix, or disc **632** which is provided with a centrally located circularly shaped aperture **633**, and the diameter of the aperture **633** is of the same order as that of an electron beam **634** arriving at the matrix disc **632** in order that the entire beam of electrons may pass through the circular aperture **633**. In order to modulate the intensity of the beam, it is possible to apply suitable signals to the horizontal and vertical deflection plates positioned between the cathode ray tube electron gun and the disc **632** so that only a portion of the electron beam, such as the portion **635**, shown in FIGURE *6b* will pass through the aperture **633**.

In addition, it is possible to eliminate an error in the position of arrival of said electron beam due to its modulation, by use of the compensating plates or by voltage adjustment of the electron lens elements positioned between the character selection plate, or disc, and the target of the cathode ray tube. Still further, as it is only necessary in accordance with the instant invention to control a comparatively low-velocity electron beam within the first low-voltage electrode which is maintained at a comparatively low potential, the magnitude of signals required for the modulation operation is in the range of the lowest driving voltages employed in cathode ray tubes so far known.

The total length of the electron gun designed in accordance with the instant invention may be further contracted or diminished, if employed only for the purpose of modulating the intensity of the electron beam to arrive at the target, thus, providing an apparatus which is capable of approaching the same order of length of general electron guns employed in conventional cathode ray tubes with the apertured disc included therein. Thus it can be seen that the instant invention provides extremely advantageous features when applied to general purpose cathode ray tubes to perform beam current modulation, as well as its application to character display cathode ray tubes.

The potentials of the first and second low-voltage electrodes employed in the cathode ray tube structure are suitably chosen to be of low enough magnitude to enhance the deflection sensitivity of the deflection plate systems, on the one hand, and yet high enough to maintain an appropriate velocity of the moving electron beam, on the other hand, and further, the electron beam paths within these low-voltage electrodes, such as the electrodes **215, 215'**, in FIGURES *2a* and *2b*, are not very long with the result that the least disturbance of the orbit of an electron beam, due to the induction of an external electromagnetic field is provided. Generally speaking, the modulated electron beam is focused on the target in the form of a spot. That is, the primary or higher order image of the cross-over, instead of the image of the configuration of the aperture in the matrix, is projected upon the target **224**.

It should be clearly understood that the configuration of the aperture in the matrix disc **632** of FIGURE *6a*, which is employed to modulate the electron beam, by no means need be limited to having a circular configuration. Any arbitrary configuration may be adopted, depending upon the needs of the user. Thus it is possible to accomplish a suitable signal voltage versus target current response by taking into account the electron density distribution in the electron beam and the configuration of the aperture and further it is possible to some extent to perform the correction of the overall gamma characteristics of the image reproduction equipment.

As has previously been mentioned, character selection and directional compensation are performed with the employment of relatively smal signall voltage magnitudes in the low potential region around the first and second low-voltage electrodes **215** and **215'**. In addition, by forming an intense convergent electric field lens in the vicinity of the matrix, as well as between the first low-voltage electrode and the accelerating grid **215** and **213** respectively, it is possible to contract or diminish the overall length of the electron gun for producing a shaped electron beam. This structure of the electron gun, designed in accordance with the instant invention, also finds application as an electron gun for controlling the current intensity of an electron beam arriving at the target which is controlled by an extremely small signal voltage employed for providing the modulation function.

Although there has been described a preferred embodiment of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not

by the specific disclosure herein, but only by the appending claims.

What is claimed is:

1. An electron beam control system for a cathode ray tube, characterized by comprising a conductive planar member containing only one aperture of any suitable configuration so that upon incidence of an electron beam on one side of the planar member a modulated electron beam intercepted partly thereof by said aperture configuration passes therethrough to emerge from the opposite side of said member, target deflection means for deflecting the electron beam which has passed through said member in moving towards a target means, an electron gun element for producing an electron beam having a fixed cross-sectional area, means controlled by an externally applied voltage for causing said electron beam to be deflected and to be incident on one side of said planar member adjacent to said aperture, and an electrostatic electron lens comprising said planar member and electrodes disposed on opposite sides of said planar member for causing an electron beam which has deviated from the deflection center of said deflection causing means to converge at a point along the central axis of the cathode ray tube; said electrodes being two cylindrical electrodes having their longitudinal axes disposed on the central axis of the cathode ray tube confronting each other with the planar member interposed therebetween and being maintained at a potential higher than the potential of said electrodes; said electron lens being a purely convergent electrostatic lens forming a convergent region around said planar member by perfectly eliminating divergent or non-convergent parts, from the region of action of said electron lens; whereby the brightness of said target means is controlled in response to the external voltage applied to said deflection causing means.

2. The system of claim 1 wherein said electron gun element further comprises at least one accelerating electrode; bias means coupled to said accelerating electrode for applying a constant D.C. voltage of a magnitude which is low enough to enhance the beam deflection means sensitivity while at the same time being high enough to maintain appropriate velocity of the moving electron beam.

3. The system of claim 1 wherein said planar member is further comprised of substantially flat supporting means, forming a planar assembly comprised of said planar member and said supporting means; said planar assembly being positioned in the equipotential plane of the electrostatic field to form an intensely convergent electrostatic lens system.

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