Dec. 24, 1940. F. H. NICOLL ET AL 2,226,439

ELECTRON GUN

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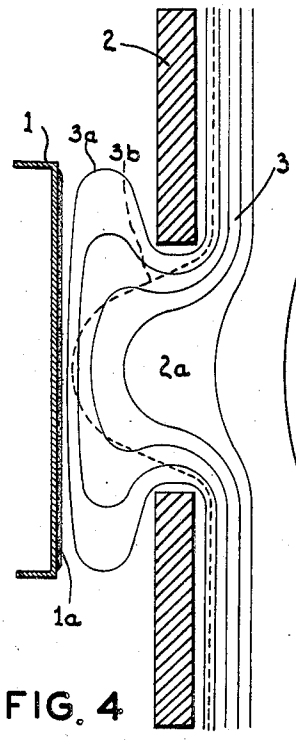


FIG. 4

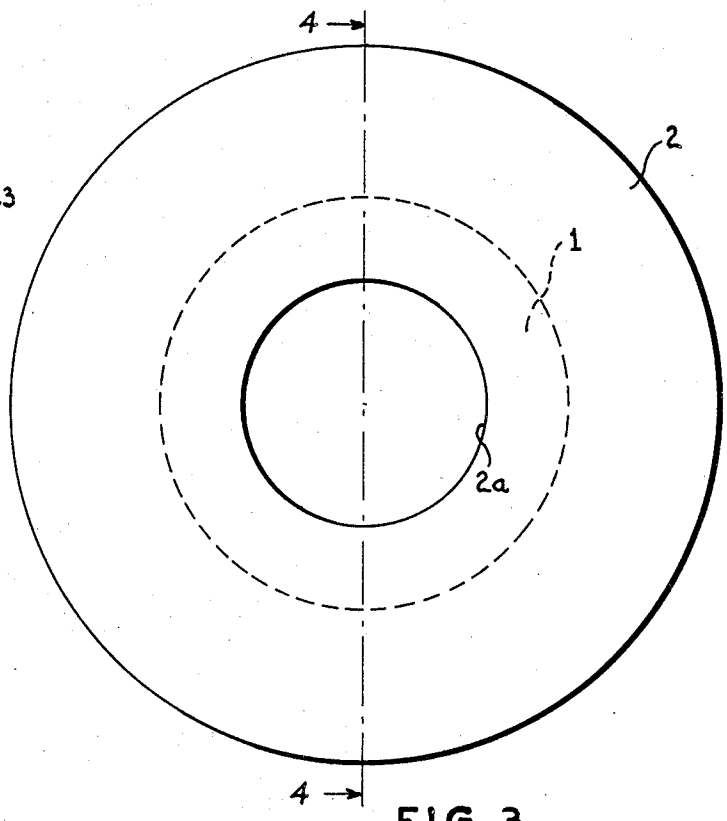


FIG. 3

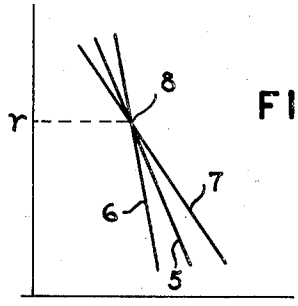


FIG. 5

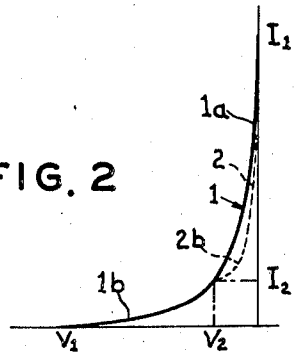


FIG. 2

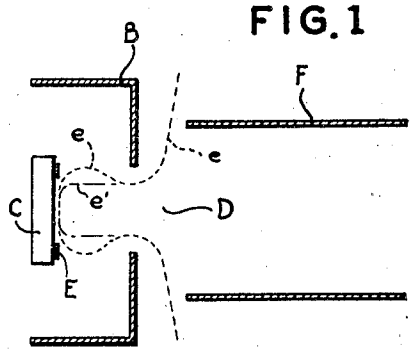


FIG. 1

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ELECTRON GUN

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5 Claims. (Cl. 250—162)

The present invention relates, more especially, but not exclusively, to electron guns, for use in cathode ray receiving tubes for television systems, in which the cathode ray beam is required to be modulated in accordance with the intensity of the signals received.

In one known form of electron gun, the gun comprises a source of electrons in the form of a plate or disc-shaped cathode arranged perpendicular to the axis of the gun, there being a modulating electrode arranged in front of the cathode and between the cathode and an accelerating electrode in such manner that electrons are drawn from the cathode past the modulating electrode. The accelerating electrode may be of tubular form and is maintained at a high positive potential relative to the cathode and relatively low negative potentials are applied to the modulating electrode, the value of the negative potential so applied varying in accordance with the intensity of the received signals so that the number of electrons drawn from the cathode by the accelerating field varies in accordance with the intensity of the received signals.

The object of the present invention is to provide an improved electron gun of the kind in which an apertured modulating electrode past which electrons are drawn substantially axially of the gun is arranged immediately in front of the cathode.

According to the principal feature of the present invention an electron gun is provided comprising in combination a source of electrons having an emitting surface presented towards an accelerating electrode, said emitting surface being in the form of a zone or part of a zone enclosing a plane central region from which substantially no emission takes place, said region having an axis of symmetry, extending perpendicularly therefrom and about which said electrodes are arranged and an apertured or gapped modulating electrode arranged about said axis in front of said source, between the source and said accelerating electrode.

According to a further feature of the invention an electron discharge device is provided comprising in combination a source of electrons having an emitting surface presented towards an accelerating electrode, said emitting surface being in the form of a zone enclosing a plane central region from which substantially no emission takes place and having an axis of symmetry extending perpendicularly therefrom and about which said electrodes are arranged and an apertured modulating electrode symmetrically arranged about said axis in front of said source between said source and said accelerating electrode, the sizes and positions of said emitting surface and said modulating electrode being such that when a positive potential is applied to said accelerating electrode and substantially zero or negative potentials are applied to said modulating electrode such that a beam of electrons is formed by electrons emitted from said source, said beam extending from said source through the aperture in said modulating electrode, a cross-over occurs in said beam at a point of which the position is substantially independent of the potential applied to said modulating electrode within the modulation range. With some arrangements for example where parallel strips from emitting cathodes are used in association with a corresponding modulating electrode the cross-over of the beam of electrons passing through the aperture or gap in the modulating electrode may occur at a line in a plane of symmetry rather than at a point on an axis of symmetry.

It is to be understood that by the term "zone" in the present specification and claims is meant a strip or belt enclosing an area.

The nature of the present invention, the method of carrying the same into effect, and the advantages of the invention will be more fully understood from the following description in detail reference being made to the accompanying drawing in which Figure 1 illustrates diagrammatically the arrangement of an electron gun in accordance with the invention, Figure 2 shows a graph which is referred to in explaining the advantages of the arrangement according to the invention,

Figure 3 is a diagrammatic front plan view of a modulating electrode and emitting cathode in a cathode ray gun,

Figure 4 is a cross section on the line 2—2 of Figure 3, and Figure 5 is a set of graphs showing the relation between the radius (plotted vertically) of an annular element in the cathode shown in Figure 3, and the distance (plotted horizontally) of the cross-over point of the annular beam of electrons emitted from the annular element in question, the three graphs representing the results obtained with different modulating potentials on the modulating electrode arranged in front of the cathode.

The electron gun arrangement shown in Figure 1 of the drawing comprises, as shown, a cathode C having an annular emitting portion E arranged symmetrically about the axis of the gun

in a plane at right angles thereto. In front of the cathode is a screen B with aperture D, the screen B constituting the electrode to which modulating potentials are applied as referred to above. In front of the screen B is provided an electrode F preferably of tubular form to which relatively high positive potentials are applied for the purpose of accelerating electrons emitted by the annulus E and causing the electrons to form a beam which constitutes the cathode ray which may, for example, be used for scanning the fluorescent screen normally provided on the end of a cathode ray receiving tube for a television system. When a negative potential is applied to the electrode B it has the effect of varying the field acting on the emissive portion E due to the accelerating electrode F in such a way that fewer electrons are drawn into the cathode ray beam by the accelerating electrode. For example, the dotted line *e* may be considered as the zero equi-potential in the case with particular potentials on electrodes F and B, the potentials being chosen such that substantially the whole of the emitting portion E of the cathode is emissive. However, if the negative potential on the electrode B is increased, when the zero equi-potential will alter to a form substantially as indicated by the chain dotted line *e'* in Figure 1, and if this negative potential is great enough substantially no emission will be obtained from the emissive portion of the cathode. Thus between certain limits of the potential applied to electrode B the effect of the applied voltage is to vary the effective outer radius of the annular emitting portion E.

The effect of using an annular emitting cathode in accordance with the invention, will be readily understood by reference to the graph of Figure 2 of the drawing. In Figure 2 the ordinates represent the cathode emission currents which are plotted against the modulating voltages applied to the electrode B as abscissae. The curve **1** shows the type of characteristic obtained with a disc-shaped cathode such as has hitherto been usually employed. As can be seen, this curve comprises of a steep upper portion *1a* where the emissions are obtained as a result of the application of low negative modulating voltages, and a much less steep portion *1b* in the region corresponding to the application of high negative modulating voltages.

Television cathode ray tubes are generally used in such manner that for no signal the screen remains dark and hence there is usually no applied biassing potential on the modulating electrode such as B of Figure 1 of the value V_2 (see Figure 2). Thus in order to make full use of the total emitting current I_1, the incoming picture signals must be amplified to give a peak voltage of V_1, it being assumed that the modulating voltage is not to be permitted to become positive with respect to the cathode so as to draw current. Furthermore, since the characteristic **1** is very curved, a graduation from black to white varying linearly with the applied signals is usually not obtained.

Now, as will be understood from the foregoing discussion with reference to Figure 1, the modulating potentials applied to the electrode B produce what may be described as an "Iris effect" in reducing the effective emitting area of the cathode C, that is to say, variation of the modulating potential causes the effective radius of the emitting area to vary, and thus it will be appreciated that the tail portion *1b* of the curve **1** gives the emission characteristic of the central portion of a disc-shaped cathode with applied modulating voltage. It would thus appear that a cathode having no central portion would have an emission characteristic comprising only a steep portion such as portion *1a* of curve **1** provided the area of the omitted central portion is large enough.

Now if a small portion of the centre of the cathode is made non-emitting, the total current I_1 available from the disc-shaped cathode will no longer be available but an amount $I_1—I_2$ will be available where I_2 is the amount of current which would be contributed by the omitted central portion of the cathode. This current is supposed to be developed with a disc-shaped cathode when a modulated potential V_2 is applied to the electrode B. Thus, with an annular cathode in which the central portion is omitted the negative bias necessary to obtain zero emission corresponding to black will now be V_2 and the picture signals applied to the modulating electrode need only be amplified such that their voltage range is from zero to V_2 instead of from zero to V_1. Moreover, the portion *1a* of the curve **1** is considerably less curved than the whole curve **1** so that the light intensity seen on the screen will vary more linearly with the applied signal voltage. Actually in practice it is found that the characteristic for an annular cathode is not quite similar in form to the portion *1a* of the curve **1** of Figure 2 but follows a curve similar to the dotted curve **2** of Figure 2. This is due to the fact that superimposed on the iris effect is a general falling off in field at the cathode as more negative bias is added. Curve **2** will be seen to have only a tail portion *2b* and thus the advantages indicated as arising from the form of the upper part of the curve **1** is largely obtained in practice notwithstanding the departure of the emission characteristic from the characteristic which might be expected from first considerations.

It is to be noted that as long as the emitting surface such as E of Figure 1 of the cathode remains symmetrical about the axis of the electrode system, the focus condition for the electron beam emitted by the cathode may remain unaltered. Furthermore an annular section of the focusing lenses is used and if this is narrow the overall aberration is correspondingly small.

It will be appreciated that while the invention has been described above particularly with reference to an annular cathode the advantages of the invention so far indicated with reference to Figures 1 and 2 of the drawing may be obtained with any strip or zonal emitting surface located on a surface disposed symmetrically about the axis of the gun, as in each case an improvement will be obtained due to the elimination of emission from the central portion of the cathode.

However, in accordance with a feature of the invention it is found that the combination of a strip form emissive cathode of a particular size and a modulating electrode similar in shape to the cathode and of a particular size in relation to the cathode for use in an electron gun, has a noticeable further advantage, namely, that it is possible to provide a gun in which the first focal point or cross-over of the cathode ray beam is formed at a substantially constant distance in front of the cathode independent of the modulating potential applied to the modulating electrode.

The effect of the change in location of the first cross-over or focal point of the cathode ray beam is troublesome in existing tubes owing to the fact that the focus condition of the cathode ray beam on the fluorescent screen varies with the applied modulating potentials. The nature of this undesired effect and also the aforesaid further advantage of the present invention will be fully understood from the following description with reference to Figures 3, 4 and 5 of the drawing.

Referring to Figures 3 and 4, it will be seen that the electrode arrangement therein shown includes a cathode **1** of circular form having a disc shaped emitting portion **1***a* in front of which is arranged a modulating electrode **2** in the form of an apertured disc having a central aperture **2***a* of considerably smaller diameter than that of the area **1***a*. Since the area **1***a* includes the central non-emitting portion or non-emitting "zone," it is obvious that the central aperture **2***a* is of smaller area than the sum of the electron emitting and non-emitting areas. The system of lines **3** in Figure 2 indicates the shape of the equi-potential lines set up in the neighborhood of the modulating electrode **2** and the cathode **1** when the modulating electrode is at the same potential as the cathode **1**, that is to say, when the modulating cathode has no bias potential applied to it. When a negative modulating potential is applied to the electrode **2**, the equipotential lines in this central region will become more curved as will be seen, for example, by comparing the same equi-potential shown in full lines at **3***a* and in dotted lines at **3***b*, before and after, respectively, the application of a negative bias potential to electrode **2**. Thus the beam of electrons emitted from the central portion of the cathode will be made to converge more sharply so that its cross-over point will move towards the cathode. Similarly, when a positive modulating potential is applied to the electrode **2**, the equipotential lines in the vicinity of the centre of the emitting area of the cathode will be rendered less curved and the cross-over of the electrons emitted from the centre of the cathode will shift away from the cathode.

However, on further considering the equipotentials shown in full lines at **3***a* and in dotted lines at **3***b*, it will be seen that when a negative modulating potential is applied to the electrode **2**, the shape of the equipotentials in the vicinity of the outer region of the emitting surface **1***a* of the cathode is completely changed, and for electrons emitted from the outer region of the cathode, when a negative modulated potential is applied to the electrode **2**, the electron crossover point is found to move away from the cathode, whilst, in the case when a positive modulating or bias potential is applied to the electrode **2** the cross-over will move towards the cathode.

It will be seen that the boundary between the two regions of the cathode in respect of which the cross-overs will vary in opposite directions with the application of a particular modulating potential to the electrode **2** will be bounded approximately by a circle of the same diameter as the aperture **2***a* in the electrode **2**.

The above described effects will be fully understood by reference to the curves in Figure 5 which represent results obtained by focusing small emissive areas of a disc shaped cathode onto a fluorescent target, the emissive areas being distributed at different distances from the centre, so that by observing the points at which the rays or beams from these areas cross the axis the cross-over point for electrons emitted from each annular element having a mean radius equal to the distance of the centre of the corresponding area or areas from the centre of the cathode could be determined. Thus Figure 5 line **5** indicates the variation in the distance of the cross-over point with the mean radius of the emitting annulus in the case when zero modulating potential or bias is applied to the electrode **2**, line **6** is a line similar to line **5** with a negative bias potential applied to the electrode **2** and line **7** is a line similar to lines **5** and **6**, but with a positive bias potential applied to electrode **2**. It will be seen that in the case shown, the variation of the distance of the cross-over point from the cathode with the radius of the emitting element is linear in each case. It will moreover be observed that the three lines **5**, **6** and **7** intersect at a single point **8** corresponding to an annulus of a particular radius *r*. Thus, it will be seen from Figure 3 that if the emitting surface of the cathode is formed as an annulus having a mean radius corresponding to the radius *r* of Figure 5, the position of the cross-over point for the cathode ray emitted from the annular cathode will be substantially independent of the modulating potentials applied to the modulating electrode. As already mentioned, the radius *r* is dependent on the form of the modulating electrode **2** and is also dependent upon the distance of the modulating electrode from the cathode **1**. For example, in a particular case the modulating electrode **2** had a thickness of 1.7 units, the distance between the cathode and the modulating electrode being 1.5 units and the diameter of the aperture **2***a* of the modulating electrode being 10 units. It was found that the diameter **2***r* of the annular element of which the cross-over point was independent of modulating potential was 9.3 units. It was further found that by doubling the separation of the cathode and the modulating electrode, the diameter **2***r* was increased to 11 units.

It will be appreciated that in some cases, curves corresponding to those shown in Figure 5 might not be strictly linear. Also, the curves might not intersect accurately at a point as shown.

The arrangement according to the invention by which shift of the cross-over point may be prevented is not only useful in connection with the cathode ray guns, it is also capable of application to electron discharge valves. For example, electrons from a strip form emitting cathode could be focussed in such a manner as to pass through an aperture in a screening grid to maintain the screen current as low as possible with varying bias, the point or line at which the beam is focussed being arranged so as to be positioned independently of modulating potentials applied to control the intensity of the beam. In this case if desired the emitting area of the cathode of the valve could have the form of two or more parallel strips, the aperture or apertures in the modulating electrode being made rectangular or the modulating electrode being constituted by two or more strips or wires arranged at either side of each of the strips of the cathode.

We claim:

1. An electron gun for an electron discharge device comprising in combination an inperforate cathode having a planar electron emitting section, said section being in the form of a zone enclosing a plane central region of said cathode having substantially no electron emitting properties, said

region having an axis of symmetry extending perpendicularly therefrom, an apertured accelerating electrode symmetrically arranged about said axis and opposite the emitting section to accelerate and focus an electron flow from said cathode as an electron beam wherein the electrons of said beam converge to a cross-over point along said axis and an apertured modulating electrode symmetrically arranged about said axis and lying between said cathode and said accelerating electrode to modulate the electron beam without varying the point along said axis toward which the electrons of said beam converge.

2. An electron gun as claimed in claim 1 wherein the emissive surface of said cathode defines a total area of substantially the same size as the area of the aperture in said modulating electrode.

3. An electron gun for an electron discharge device comprising in combination an imperforate metallic cathode, electron emitting material to form an emitting surface on said cathode, said emitting surface being in the form of parallel strips arranged in a common plane separated one from the other and on either side of an axis of symmetry normal to said plane and leaving a non-electron-emitting section of said cathode therebetween, an apertured accelerating electrode symmetrically disposed with respect to the said strips with the aperture directly opposite the non-emitting section of said cathode, said accelerating electrode being symmetrically disposed with respect to said axis of symmetry and spaced from said cathode along said axis of symmetry to accelerate electrons emitted from said cathode, and a modulating electrode between said accelerating electrode and said cathode comprising separated portions each of which is equidistant from said axis of symmetry and extends parallel to the emitting strips on said cathode.

4. An electron gun comprising in combination an imperforate cathode, electron emitting material defining a plane emitting surface on said cathode, said emitting surface being in the form of a zone enclosing a plane central non-electron emitting region of said cathode which is coplanar with said emitting surface and from which substantially no emission takes place, said region having an axis of symmetry extending perpendicularly therefrom, an accelerating electrode comprising an apertured disk symmetrically positioned about said axis and an apertured modulating electrode arranged about said axis between said cathode and said accelerating electrode.

5. An electron gun as defined in claim 4 wherein the said emitting material defines an emitting surface which is annular and encloses a central non-electron emitting portion of said cathode and wherein the sum of the areas of said emitting material and said central portion is equivalent to the area of the aperture in said modulating electrode.

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