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Hunter

[11] 3,852,633

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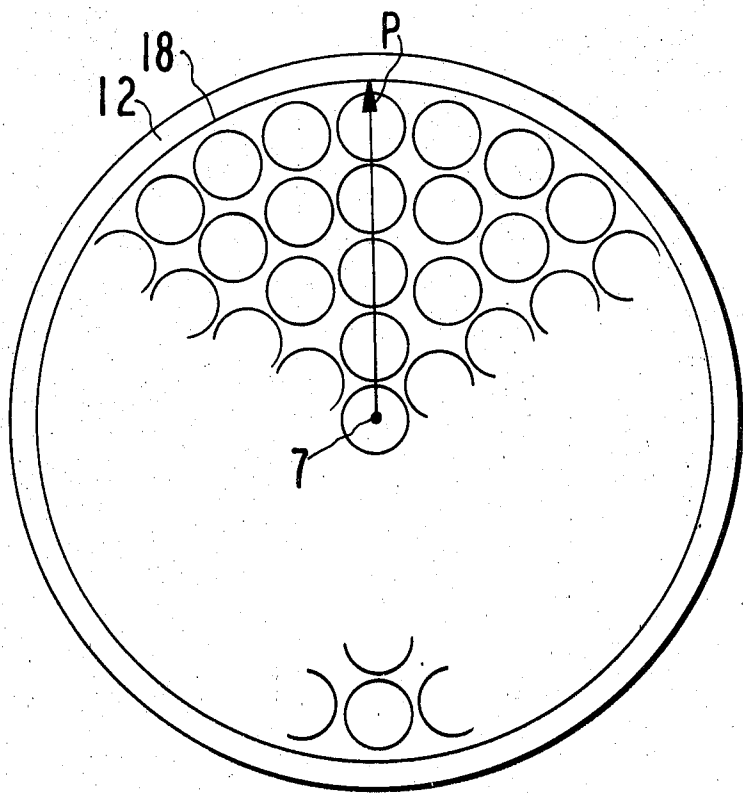
[54] **GRIDDED ELECTRON GUN**
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[73] Assignee: **Varian Associates**, Palo Alto, Calif.
[22] Filed: **Dec. 13, 1972**
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[52] U.S. Cl. **313/411, 313/414, 313/348, 315/3.5**
[51] Int. Cl. **H01j 29/00**
[58] Field of Search 315/3.5, 5.34; 313/82, 313/348, 82 R, 82 BF

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Assistant Examiner—Saxfield Chatmon, Jr.
Attorney, Agent, or Firm—R. K. Stoddard; H. E. Aine

[57] **ABSTRACT**
The control grid structure for a convergent flow electron gun includes a corrective electrostatic lens associated with each of the beam passageways through the grid. The corrective electrostatic lenses increase in focusing strength taken from the outside of the beam toward the center of the beam to compensate for beamlet defocusing forces occasioned by the relatively large central aperture in the anode of the gun. In a preferred embodiment, the corrective electrostatic focusing lens structure comprises a second control grid portion interposed between a first control grid portion and the anode. The second control grid portion is thermally shielded from the cathode via the first grid portion for inhibiting unwanted thermionic emission from the composite control grid structure.

6 Claims, 10 Drawing Figures



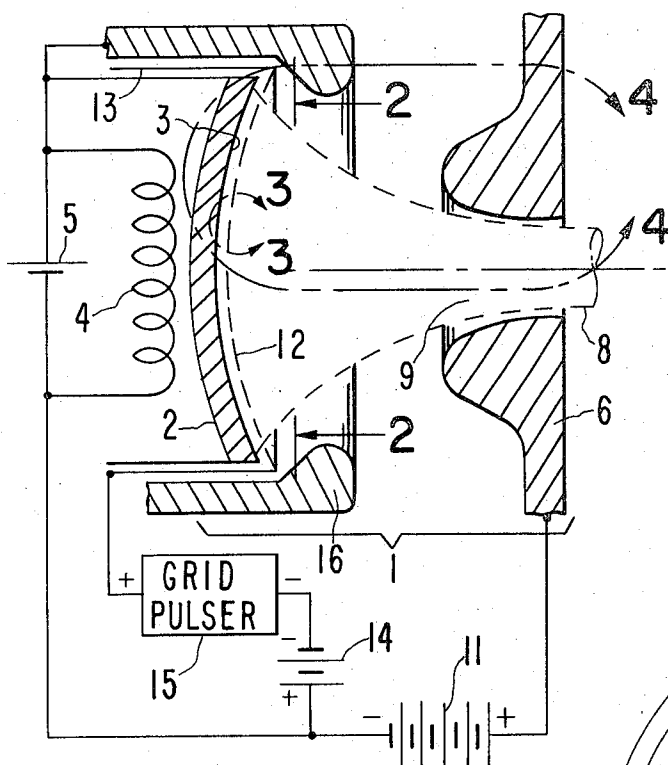


FIG. 1

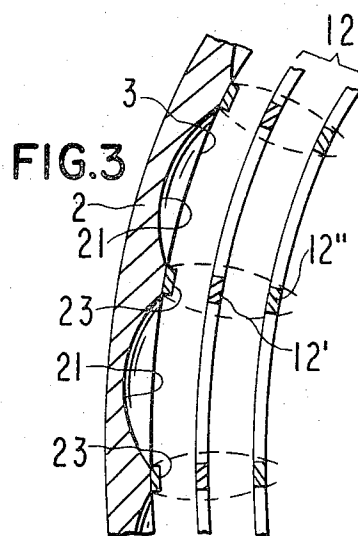


FIG. 3

FIG. 2

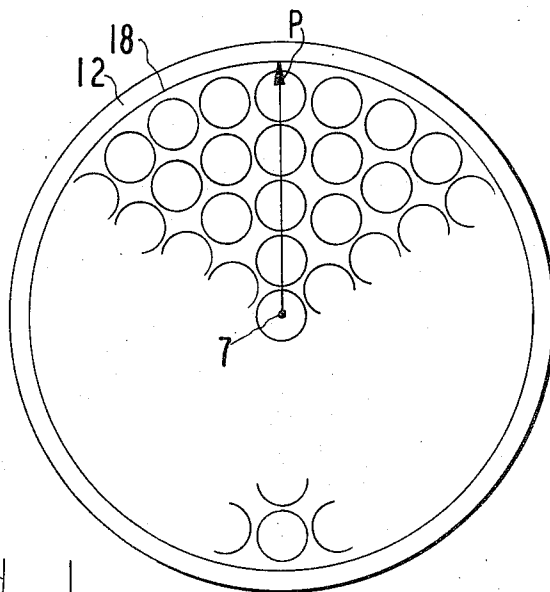
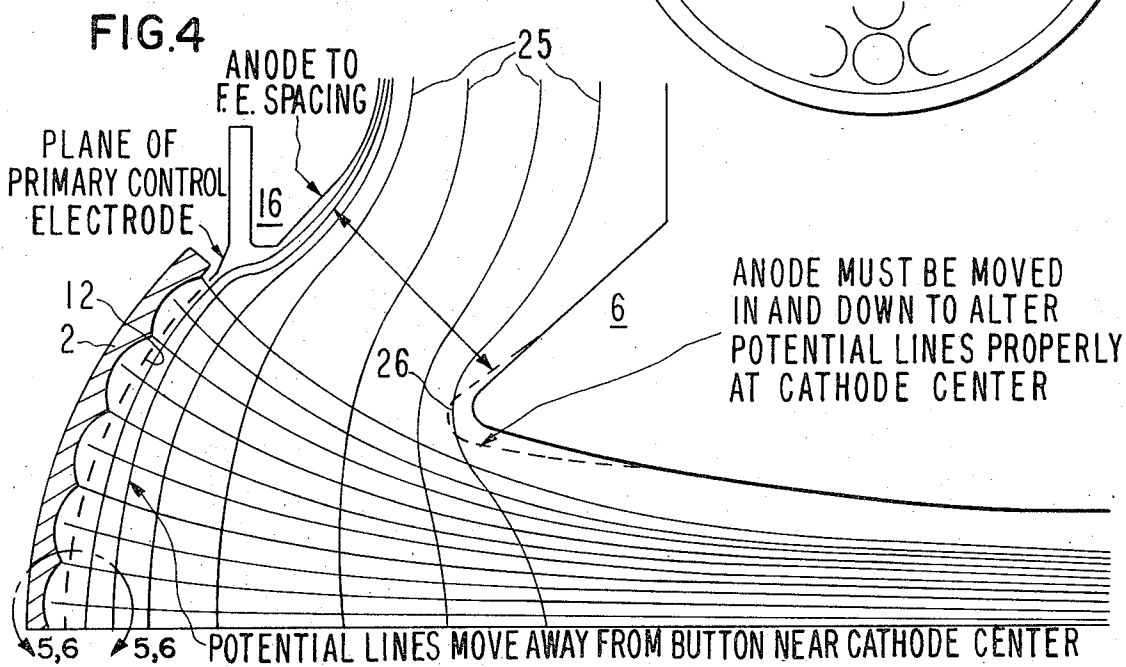


FIG. 4

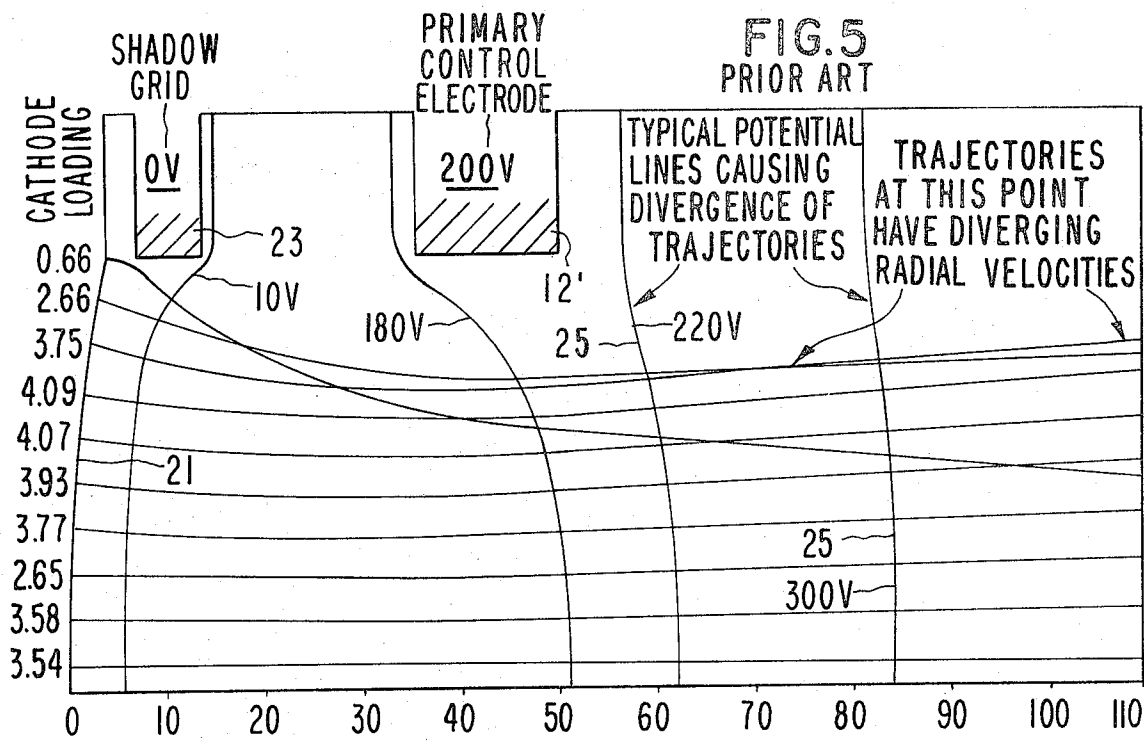
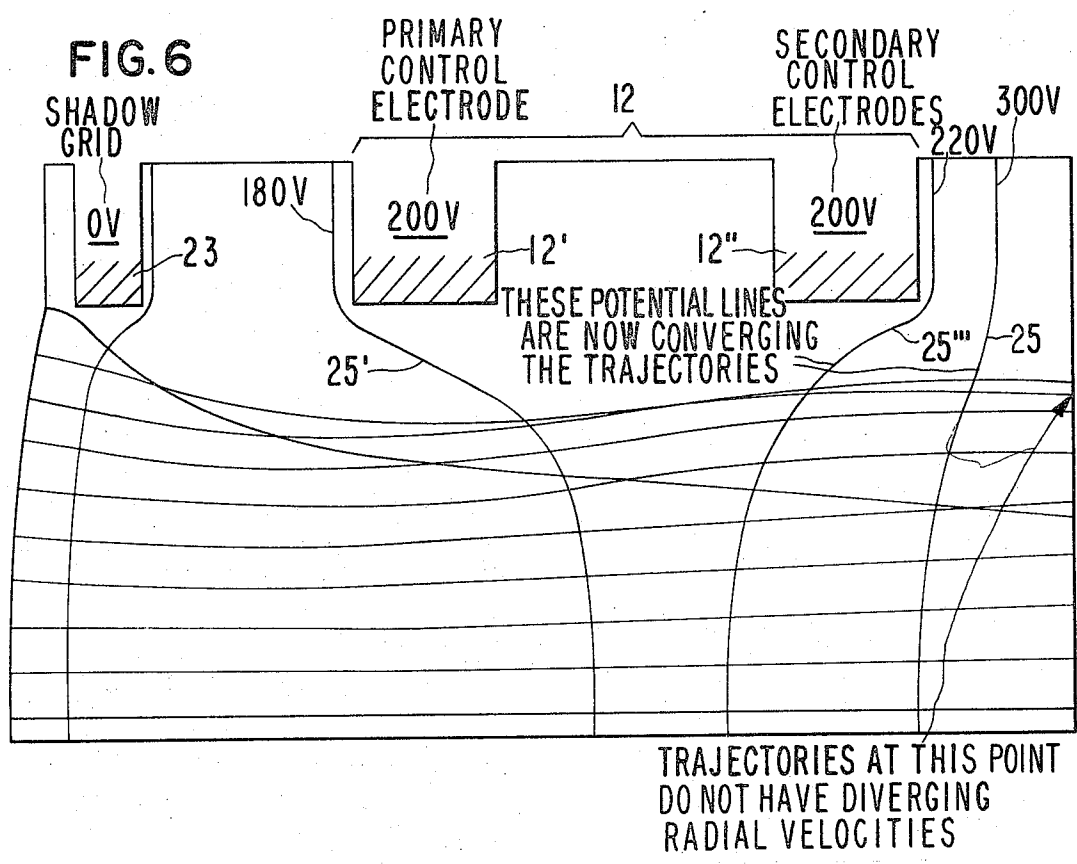


FIG. 7

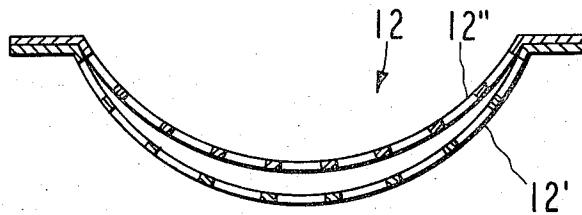


FIG. 10

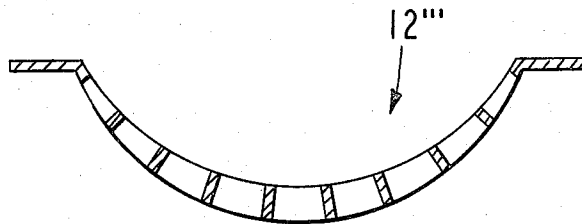


FIG. 8
PRIOR ART

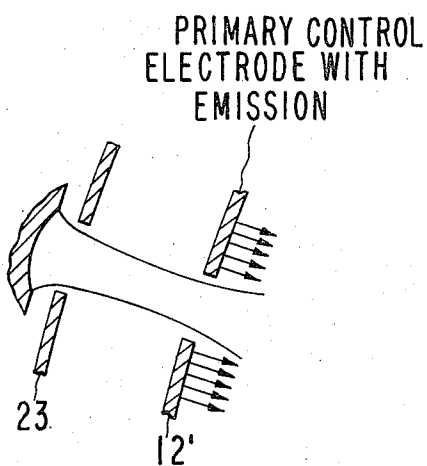
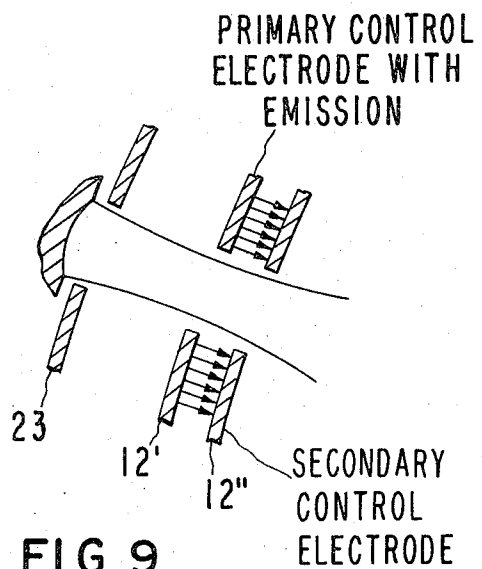


FIG. 9



GRIDDED ELECTRON GUN

BACKGROUND OF THE INVENTION

The present invention relates in general to gridded convergent flow electron guns and, more particularly, to an improved control grid structure for such guns which reduces undesired beam aberration, allows increased beam convergence, and which reduces unwanted interpulse noise caused by undesired thermionic emission from the control grid structure.

BRIEF DESCRIPTION OF THE PRIOR ART

Heretofore, gridded convergent flow electron guns have been built wherein the control grid comprised a multi-apertured spherically concave cathode emitting surface of a thermionic cathode emitter for controlling the convergent flow of electrons from the concave cathode emitting surface through a central aperture in an anode structure. The control grid comprised a multitude of grid openings or beam passageways of uniform cross-sectional dimensions for producing a multiplicity of individual beamlets which passed through the control grid in a substantially non-intercepting manner and thence into a confluent flow of electrons through the central aperture in the anode to produce a pencil-like cylindrical beam of electrons. In a preferred embodiment, the spherically concave cathode emitting surface was dimpled with a multiplicity of lesser spherically concave cathode emitting surfaces forming the composite spherically concave cathode emitting surface. The lesser concave cathode emitting surfaces were each aligned along the beam path with the respective openings in the control grid so as to minimize interception of current on the control grid structure. Such a gridded electron gun is disclosed and claimed in U.S. Pat. No. 3,558,967 issued Jan. 26, 1971 and assigned to the same assignee as the present invention.

One of the problems with this prior art control grid structure is that the relatively large central aperture in the anode produces a distortion in the equipotential lines adjacent the central region of the control grid structure. This distortion of equipotential lines adjacent the control grid structure causes the central portion of the control grid structure to act as a defocusing lens producing a substantial defocusing of the individual beamlets near the center of the control grid structure. This defocusing force produces a substantial radial velocity to the electrons in the beamlets passing through the central portion of the control grid and therefore reduces the convergence of the composite beam. Heretofore, attempts have been made to improve the convergence of the beam by extending an annular nose portion at the lip of the central opening in the anode structure toward the center region of the control grid but this has a deleterious effect of reducing the high voltage holdoff potential that can be established between the control grid and anode.

In addition, another problem encountered in the prior art control grid structure is that the control grid is closely spaced to the thermionic cathode emitter such that the control grid is heated by radiation. If the temperature of the control grid becomes excessive, thermionic emission is obtained from the control grid which increases the interpulse noise, i.e., grid emission produces an output when the grid is pulsed negative for turning off the beam.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved gridded electron gun.

In one feature of the present invention, an electrostatic beam focusing structure is associated with the multi-apertured control grid for providing an increasing beamlet focusing force toward the center of the control grid structure to compensate for distorted equipotential lines between the control grid and the centrally apertured anode of the electron gun.

In another feature of the present invention, a second control grid structure is associated with the primary control grid, such secondary control grid structure being interposed between the primary control grid and the anode. The secondary control grid is thermally shielded from the thermionic cathode emitter by the primary control grid and thus operates at a low temperature for reducing undesired thermionic emission from the control grid structure during periods when the control grid is pulsed negative for turning off the beam current.

In another feature of the present invention, the length of the individual beam passageways through the control grid structure increases toward the center of the control grid for providing an increasing focusing force on the individual beamlets taken in the direction toward the center of the control grid structure for improving the beam convergence of the composite beam, and for increasing the standoff voltage between the control grid and anode by allowing the anode to be moved further from the control grid structure for a given beam convergence.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic longitudinal sectional view, partly in block diagram form, of a gridded electron gun incorporating features of the present invention,

FIG. 2 is an enlarged plan view of a portion of the structure of FIG. 1 taken along line 2—2 in the direction of the arrows showing the pattern of beam apertures in the control grid,

FIG. 3 is an enlarged detail view of a portion of the structure of FIG. 1 delineated by line 3—3,

FIG. 4 is an enlarged detail view of a portion of the structure of FIG. 1 delineated by line 4—4 and showing the equipotential lines in the electron gun assembly,

FIG. 5 is an enlarged detail view of a portion of the structure of FIG. 4 delineated by line 5—5 and depicting the equipotential lines for a control grid beamlet near the center of the composite cathode emitter using only a single control grid of the prior art,

FIG. 6 is a view similar to that of FIG. 5 depicting the pattern of equipotential lines and beam trajectories for a control grid beamlet near the center of the control grid structure of the present invention,

FIG. 7 is a longitudinal sectional view of a control grid structure incorporating features of the present invention,

FIG. 8 is a schematic longitudinal sectional view of a control grid beamlet of a prior art electron gun showing thermionic emission from the control grid structure,

FIG. 9 is a view similar to that of FIG. 8 depicting how the control grid structure of the present invention inhibits thermionic emission from the control grid structure, and

FIG. 10 is a view similar to that of FIG. 7 depicting an alternative control grid structure of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a gridded convergent flow electron gun 1 incorporating features of the present invention. The gun 1 includes a thermionic cathode emitter 2, as of the dispenser or oxide coated nickel type, having a spherically concave cathode emitting surface 3 for supplying copious electron emission when heated to its operating temperature via a heating element 4 disposed in heat exchanging relation with the cathode 2. A filament power supply 5 supplies electrical power to the heating element 4. A centrally apertured anode disc 6, as of copper, is axially spaced along an axis of revolution 7 from the concave cathode emitting surface 3. The central aperture 8 in the anode has a flared entrance portion 9 and a constricted neck portion having a transverse cross-sectional area substantially smaller than the transverse cross-sectional area of the emitter 3 such that a substantial convergent flow of electrons is obtained from the cathode emitter 3 through the central aperture 8 in the anode 6 when a suitable positive potential is applied to the anode 6 relative to the cathode emitter 2 via anode supply 11.

A spherically concave multi-apertured control grid 12, as of molybdenum or tungsten, is disposed closely overlaying the concave cathode emitting surface 3 for controlling the flow of electrons from the cathode emitting surface 3 through the anode 6. The control grid 12 is supported at its outer periphery via a cylindrical support structure 13 disposed in thermally and electrically insulative relation relative to the cathode 2. A grid bias supply 14 supplies a DC negative grid bias to the control grid 12 so that the control grid is normally biased off, i.e., the beam current is off. A grid pulser 15 is series connected with supply 14 for applying a positive pulse of sufficient magnitude such that the control grid 12 is pulsed positive relative to the cathode 2 for pulsing the beam current through the anode. A beam focus electrode 16, typically operated at cathode potential, is provided surrounding the control grid 12 to aid in focusing the electron beam through the central aperture in the anode 6 in a substantially non-intercepting manner.

A more detailed description of the electron gun 1 and tubes using same is found in the disclosure of the aforementioned U.S. Pat. No. 3,558,967, which is hereby incorporated by reference.

Referring now to FIG. 2 there is shown the control grid hole pattern. More particularly, the holes are arranged in the spherically concave surface of the control grid structure in a plurality of concentric circular rows. One hole is preferably centered in the center of the grid 12 on the axis of revolution 7 of both the control grid and the underlying cathode emitter. The outer periphery 18 of the underlying cathode emitter 3 determines the outer peripheral boundary for the hole pattern. This defines a spherical peripheral line P extending from the axis of revolution 7 along the concave surface

of the control grid to the perimeter 18. Peripheral line P can accommodate so many circular rows of holes of a given size without the holes intersecting each other, i.e., the holes being a little less than tangent along the spherical line P. Once the number of rows and hole size has been decided, the holes of this size are merely equally spaced around each of the concentric rows beginning from the starting line P. The result is a circular array of closely spaced holes with an overall beam transparency of between 65 and 75%. Such a control grid is disclosed and claimed in copending application Ser. No. 293,205 filed Sept. 28, 1972, now abandoned, and assigned to the same assignee as the present invention.

Referring now to FIG. 3 there is shown the control grid 12 closely spaced to the spherically concave emitting surface 3 of the cathode emitter 2. In a typical example, the spacing from the cathode emitter surface 3 to the convex surface of the control grid 12 is approximately 0.039 inches. The spherically concave control grid 12 has a radius of curvature slightly less than that of the concave cathode emitting surface 3. Both the emitter 3 and grid 12 have a common center of curvature such that uniform spacing is obtained between the emitting surface 3 and the control grid 12.

The composite concave cathode emitting surface 3 is formed by an array of spherically concave dimples 21 arranged in a circular pattern of uniform size corresponding to the similar hole pattern of control grid 12, such that the centers of the individual dimples 21 are axially aligned along the beam path with the centers of the registered holes in the control grid 12. The dimples 21 have a radius of curvature which is substantially less than that of the composite surface 3 to define, with the corresponding grid holes, a multiplicity of convergent flow electron guns to generate a multiplicity of non-intercepting control grid electron beamlets 22 for projecting the grid controlled electron beam through the control grid 12 in a non-intercepting manner. The beamlets converge into a unitary beam after passage through the control grid.

A shadow grid 23, preferably of nickel in the case of a nickel oxide coated cathode, has a hole pattern corresponding to the hole pattern in the control grid 12 and has a radius of curvature equal to that of the emitting surface 3. The shadow grid 23 is disposed in nominal contact with the web portion of the emitting surface 3 to inhibit emission from that portion of the cathode emitter surface 3 which is opposite the individual web portions of the control grid 12, whereby undesired grid interception is prevented.

The control grid 12 includes a primary control grid portion 12' and a secondary control grid portion 12'' axially spaced apart along the direction of the beam to define a multitude of control grid beamlet passageways through the aligned openings in the composite grid structure 12. The secondary control grid portion 12'' has a radius of curvature which is larger than the radius of curvature of the first or primary control grid member 12' such that the spacing along the direction of the beam path between the primary and secondary control grid portion 12' and 12'' increases toward the center of the composite control grid structure 12. This increase in the length of the beam passageways through the individual aligned openings in the control grid structure 12 toward the center of the composite grid structure 12 serves to produce electrostatic beam fo-

cusing lenses of increasing magnitude taken in the direction toward the center of the composite grid structure from its outer periphery. This is for the purpose of compensating for an otherwise increasing defocusing electrostatic lens effect caused by the equipotentials moving away from the surface of the control grid structure near the central portion of the control grid, as more clearly shown in FIG. 4.

Referring now to FIG. 4, there is shown the pattern of electrostatic equipotentials 25 in the region between the cathode 2 and anode 6. As can be seen from the plot of FIG. 4, the equipotential lines bow away from the center of the control grid 12 toward the central opening 6 in the anode. When the equipotentials bow away from the plane of the control grid 12, the equipotential lines at the control grid potential tend to bow away from the cathode 2 at the beam entrance apertures of the control grid structure 12. This produces an electrostatic defocusing force on the electrons of the individual beamlets passing through the grid structure 12. This defocusing force tends to increase in magnitude toward the center of the control grid and that portion of the beam which originates from the central region of the cathode emitter 2 has imparted thereto a substantial transverse velocity thereby reducing the overall convergence of the electron beam.

In the prior art, wherein only one very thin control grid portion 12' was utilized for controlling the beam (see FIG. 5), attempts were made to counteract this beam divergent effect near the center of the beam by moving the annular anode nose portion closer into the center of the control grid and cathode 2, as indicated by dotted line 26 of FIG. 4. While moving the nose portion of the anode in closer to the control grid 12' and toward the center of the control grid 12' served to improve the shape of the equipotentials and to decrease the divergence of the beamlets near the center of the control grid, it also had the undesired effect of decreasing the spacing between the focusing electrode 16 and anode 6 such that the maximum hold off voltage (beam voltage) between the focusing electrode and the anode was substantially reduced. Since the maximum hold off voltage determines the maximum beam voltage of the electron gun it is desirable to provide means for compensating for the bowed equipotential lines in such a manner that the maximum beam voltage is not deleteriously affected.

Referring again to FIG. 5, there is shown the plot of equipotentials in the vicinity of the primary control grid portion 12' in the case of the prior art control grid structure which included only one control grid portion 12'. The plot of FIG. 5 is for a beamlet generated near the center of the control grid structure such that the outward bowing of equipotential lines in the vicinity of the control grid produces a substantial defocusing or radial velocity component to the electrons of the beamlet passing through the control grid 12'.

Referring now to FIG. 6 there is shown a plot similar to that of FIG. 5 for the control grid structure of FIG. 3 having axially spaced grid portions 12' and 12''. As can be seen from the plot of the equipotential lines 25, the inwardly dished equipotential line 25' at the beam entrance aperture of the primary control grid 12' is compensated for by an oppositely dished equipotential line 25'' produced at the exit of the beamlet passageway through the control grid electrode 12. This inwardly dished equipotential line 25'' at the exit of the

beamlet passageway through the control grid 12 is produced by the secondary control grid portion 12'' and produces a substantial corrective focusing force upon the electrons of the beamlet, thereby compensating for the divergent lens effect produced by the primary control grid portion 12'. Thus, by the provision of the secondary control grid portion 12'', the diverging effect of bowed equipotential lines near the center of the control grid structure is substantially compensated to increase the convergence of the electron beam and to reduce radial aberrations, thereby increasing the laminarity of the resultant electron stream. Increased convergence allows the minimum beam diameter to be decreased. This result is achieved without deleteriously affecting the voltage hold off of the electron gun 1.

Another advantage of the control grid 12 employing first and second control grid portions 12' and 12'' is that the thermionic emission from the primary control grid portion 12' is intercepted by the web of the secondary control grid portion 12''. In addition the secondary control grid portion 12'' is thermally shielded from the high temperature cathode emitter 2 by the primary control grid portion 12' such that the secondary control electrode portion 12'' operates at a lower temperature and thus thermionic emission from the control grid structure is substantially reduced. This greatly reduces interpulse noise. This control of the thermionic grid emission is depicted in FIGS. 8 and 9 where FIG. 8 shows the prior art grid having thermionic grid emission and FIG. 9 shows the structure of the present invention employing the axially spaced primary and secondary control grid portions 12' and 12''.

Referring now to FIG. 7 there is shown the control grid structure 12 of the present invention. More particularly it is seen that the spacing between the primary control grid portion 12' and that of the secondary control grid portion 12'' increases toward the center of the control grid 12 for increasing the strength of the electrostatic focusing lens action of the secondary control grid portion 12'' toward the center of the control grid structure 12.

Referring now to FIG. 10 there is shown an alternative control grid embodiment of the present invention. Control grid 12''' of FIG. 10 is similar to the control grid structure of FIG. 7 with the exception that grid 12''' is formed of a single member as contrasted with the primary and secondary grid members 12' and 12''. In the single piece grid 12''' the beamlet passageways through the grid structure 12''' have lengths that increase from the outer periphery toward the center of the control grid structure to produce the increasing corrective beam focusing lens effect at the beam exit ends of the beamlet passageways through the grid structure to compensate for the outward bowing of the equipotential lines near the center of the composite grid structure, in the same manner as previously described for the grid of FIG. 7.

What is claimed is:

1. In a gridded electron gun:

thermionic cathode emitter means having a concave cathode emitting surface for providing a copious supply of electrons;

anode electrode means spaced from said concave cathode emitting surface and having a central aperture in axial alignment with said concave cathode emitting surface for drawing a beam of electrons

from said cathode through said central aperture in said anode;

concave control grid means interposed between said concave cathode emitting surface and said anode means, said concave control grid means including a plurality of beam passageways therethrough of generally uniform cross-sectional area defining electrostatic focusing lenses for focusing said electrons into individual beamlets passable there- through, said individual focusing lenses of said control grid increasing in length from the outer periph- 5 ery toward the center of said control grid, said control grid means being operative at a varying control grid potential relative to said cathode emitter means.

2. The apparatus of claim 1 wherein said control grid means includes first and second axially spaced concave apertured control grids, said control grids being dis- posed adjacent each other with their respective aper- tures in axial registration, means for interconnecting 20 said first and second control grids to be operated at the same control grid potential, and wherein the axial spac- ing between said first and second control grids in- creases from the outer periphery toward the center of said control grids to provide the increase in length for the individual electrostatic lenses formed by the re- 25 spective beam passageways through said aligned aper- tures in said control grids.

3. The apparatus of claim 1 wherein said central ap- 30 erture in said anode means has a lesser transverse cross-sectional area than said emitting surface of said cathode emitter for producing a convergent flow of electrons from said cathode emitter through said cen- tral aperture in said anode electrode means.

4. The apparatus of claim 1 including, concave 35 shadow grid means interposed in the space between said control grid means and said concave cathode emit- ting surface of said cathode emitter means, said shadow means having beam apertures in alignment with the re- 40 spective beam apertures in said control grid means, and

means for operating said shadow grid means at the same potential as said cathode emitter means.

5. The apparatus of claim 4 wherein said concave cathode emitting surface of said concave cathode emit- 5 ter means is constituted of a plurality of dimpled re- gions in alignment along the beam path with respective beam passageways in said shadow and control grid means, said dimpled regions being curved in mutually orthogonal directions and having radii of curvature substantially less than that of said composite concave cathode emitting surface.

6. In a gridded electron gun:

thermionic cathode emitter means having a concave cathode emitting surface for providing a copious 15 supply of electrons;

anode electrode means spaced from said concave cathode emitting surface and having a central aper- ture in axial alignment with said concave cathode emitting surface for drawing a beam of electrons from said cathode through said central aperture in said anode;

concave control grid means interposed between said concave cathode emitting surface and said anode means, said concave control grid means including a plurality of beam passageways therethrough of generally uniform cross-sectional area,

said control grid means including first and second ax- ially spaced concave apertured control grid por- tions, said control grid portions being disposed ad- jacent each other with their respective apertures in axial registration, means for interconnecting said first and second control grid portions to be oper- ated at the same control grid potential, whereby the second control grid portion closest to said anode is thermally shielded from the cathode by said first control grid portion to reduce thermionic emission from said composite control grid struc- 40 ture to reduce undesired interpulse noise.

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