ABSTRACT: A gridded electron gun for linear beam tubes is disclosed. The electron gun includes a concave cathode emitter formed by a mosaic of a multitude of lesser cathode emitting surfaces. The lesser cathode emitting surfaces are concave with a radius of curvature substantially less than the radius of curvature of the composite cathode emitter. A multipertured control grid is closely spaced to and shaped to conform to the concave surface of the cathode emitter. The apertures in the control grid are in alignment with the individual ones of the cathode emitting surfaces to produce a multitude of convergent beamlets passing through the apertures in the grid in a substantially nonintercepting manner. The beamlets converge together into a confluent electron stream passing through a central aperture in an accelerating anode to form a unitary electron beam for a linear beam tube. The control grid may have a $\mu_s$ of between 20 and 100 and provide grid interception of less than 0.2 percent of the beam current. In a dispenser cathode a second grid, which is essentially identical to the control grid, is incorporated in or on the surface of the cathode either in contacting or noncontacting relation therewith.
LINEAR BEAM TUBE WITH PLURAL CATHODE BEAMLETS PROVIDING A CONVERGENT ELECTRON STREAM

This is a continuation of Ser. No. 650,893 filed Jul. 3, 1967 now abandoned.

DESCRIPTION OF THE PRIOR ART

Heretofore, mosaic cathode emitters have been utilized with multiapertured control grid electrodes to produce an electron beam formed by a plurality of separate beamlets. An example of such a prior art electron gun is described in U.S. Pat. No. 3,107,313, issued Oct. 15, 1963. In this prior art tube, the object was to separate the beams into individual beamlets to avoid a potential depression in the center of the beam and to obtain improved coupling to the beam by means of gridded electrodes disposed along the beam path. While such a multi-beam tube structure is suitable at low beam voltages and relatively low beam power it is not generally suitable for high power linear beam tubes operating at microwave frequencies where the beam must be compressed into a relatively small region of the microwave circuit for interaction with the electromagnetic fields of the microwave circuit.

Other prior attempts to provide nonintercepting control grids for convergent electron beams have involved the use of highly transparent grids, either closely spaced to the concave cathode-emitting surface or actually disposed on the surface of the cathode emitter. When the grid is placed essentially on the surface of the cathode emitter it tends to shield a relatively large region of the cathode-emitting surface from the strong accelerating fields of the anode structure such that substantially all of the emission from the cathode emitter is drawn from a relatively small area of the cathode. The result is a current overloading of the cathode-emitting surface and failure of the cathode emitter. In cases where a concave highly transparent control grid has been utilized in close proximity to the surface of the cathode emitter, interception of the electron current by the grid has been on the order of a few percent which is excessive for high power beam tubes resulting in destruction of the grid.

SUMMARY OF THE PRESENT INVENTION

Principal object of the present invention is the provision of an improved gridded electron gun for high power linear beam tubes.

One feature of the present invention is the provision, in a convergent linear beam tube, of a concave cathode emitter formed by a mosaic of lesser cathode emitters, said lesser cathode emitters having emitting surfaces with a smaller radius of curvature than the concave surface of the composite emitter, and a multiapertured control grid closely spaced to the concave emitter and conforming to the concave shape thereof with the apertures in the control grid in axial alignment with the individual ones of the cathode emitters, whereby a nonintercepting control grid is provided.

Another feature of the present invention is the same as the preceding feature wherein the linear beam tube is a velocity-modulated tube having a radio frequency wave supportive structure for electromagnetic interaction with the beam to produce an output radio frequency signal.

Another feature of the present invention is the same as any one or more of the preceding features including the provision of a second multiapertured grid structure substantially identical to the first control grid (shadow grid) incorporated substantially in or on the surface of a dispenser cathode emitter and conforming to the concave shape of the cathode emitter with the apertures in the second grid being substantially in alignment and coextensive with the apertures in the control grid, whereby unwanted thermionic emission from the marginal edges of the lesser cathode surfaces is inhibited in use and improved focusing of the beamlets through the control grid is obtained.

Another feature of the present invention is the same as the immediately preceding feature wherein the second grid structure is supported at its periphery by a heat making member, such grid being disposed in noncontacting relation within a recess in the concave cathode emitter surface to facilitate cooling of the second grid relative to the temperature of the cathode.

Another feature of the present invention is the same as any one or more of the preceding features including a magnetic beam focusing structure for producing an axially directed magnetic field in the convergent electron stream for focusing the electron stream over an elongated beam path to a beam collector structure.

Another feature of the present invention is the same as the preceding feature wherein the magnetic beam focusing structure causes the beam confining magnetic field to thread through the concave cathode-emitting surface for focusing the electron stream in the region between the cathode emitter and the accelerating electrode of the electron gun.

Another feature of the present invention is the same as any one or more of the preceding features wherein the apertures in the multiapertured control grid are hexagonally shaped.

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 longitudinal sectional view of a portion of an electron gun incorporating features of the present invention;

FIG. 2 is a reduced view of a portion of the structure of FIG. 1 taken along line 2-2 of FIG. 1;

FIG. 3 is a longitudinal schematic sectional view of an electrostatically focused tube incorporating features of the present invention;

FIG. 4 is a longitudinal sectional view of a magnetically focused embodiment of the present invention;

FIG. 5 is a schematic longitudinal sectional view of an alternative magnetically focused tube of the present invention;

FIG. 6 is a schematic longitudinal sectional view of an alternative magnetically focused tube of the present invention;

FIG. 7 is an enlarged cross-sectional detail view of the portion of the structure of FIG. 1 delineated by line 7-7 and depicting an alternative arrangement employing a shadow grid on the surface of the cathode emitter;

FIGS. 8 and 10 are views similar to that of FIG. 7, taken at the marginal edge of the cathode emitter, and incorporating alternative features of the present invention; and

FIGS. 8, 9 and 11 are enlarged detail views of portions of FIGS. 8 and 10 delineated by lines 9-9 and 11-11, respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is shown the gridded electron gun of the present invention. The gun 1 includes a concave cathode emitter 2, as of nickel, disposed with its emitting face 3 in axial alignment with and spaced from a central aperture 4 in an accelerating electrode 5. The concave emitter 2 is formed by a spherical section having a radius of curvature R approximately equal to the spacing from the spherical emitter 2 to the center of the entrance to the aperture 4 in the accelerating electrode 5.

The emitting surface 3 of the emitter 2 is constituted by a multitude of individual concave cathode-emitting surfaces 6. A multiapertured control grid 7, as of molybdenum or tungsten, is closely spaced and shaped to conform to the concave face 3 of the emitter 2. The apertures 8 in the control grid 7 are axially aligned with individual ones of the concave cathode emitters 6 to form a multitude of individual electron guns. Each electron gun produces a convergent nonintercepting beamlet passing through an aperture 8 in the control grid 7. In this manner, interception of the beam current by the apertured control grid 7 is reduced to an extremely small amount as of, for example, 0.2 percent. In addition, uniform electron emission is obtained from essentially the entire surface of the cathode emitter 2, see FIG. 2.
In a typical example, the control grid 7 is spaced approximately 0.039 inches from the cathode and the individual emitter surfaces 6 are coated with a thin coating of oxide cathode material to form the composite cathode emitter 2 having an operating temperature of approximately 800° C. The grid 7 has a μ of approximately 70, a cutoff, i.e.,

$$\frac{I_c}{I_1}$$

A, of about 200, and is employed in a linear beam tube having a 4 percent duty cycle at 10 kv beam voltage and 2 percent of beam current. The grid has a grid interception of less than 0.2 percent of the beam current. The gridron electron gun of the present invention may also be employed for CW operation.

The individual cathode emitting surfaces 6 are spherical sections and have a circular outer dimension thereby leaving a nonemissive gridlike structure defined in the face 3 of the cathode emitter 2 which will be nonemissive and which is generally in alignment with the shadow produced by the control grid 7. In a preferred embodiment, the control grid 7 has hexagonally shaped grid openings 8 to provide a maximum transparency to the electron beamlets.

After each of the individual beamlets has passed through the nonintercepting control grid 7, the beamlets converge and each beamlet spreads due to space charge forces such that all of the beamlets blend together and are converged into a unitary beam passing through the central aperture 4 in the accelerating electrode 5.

One method for fabricating the cathode emitter 2 is to first mount the multiapertured grid 7 with the proper spacing on the spherical face 3 of the cathode emitter 2. A scribing tool is then inserted through each of the apertures 8 in the grid 7 with the scribe being inserted along a radial line emanating from the center of curvature 11 of the cathode emitter 2. The scribe marks the center of each of the individual cathode emitters 6 and defines the outer periphery thereof. The grid 7 is then removed and a punch having a spherically curved end is struck into the face 3 of the cathode emitter 2 to produce the spherically shaped cathode emitting surfaces 6. The punched cathode emitter is then coated with a coating of the electron emissive material and processed in the conventional manner. Although the cathode emitter 2 has been described as a nickel oxide cathode, other types of cathodes can be made to include the individual concave cathode-emitting surfaces 6. Such other cathodes may include, for example, dispenser cathodes and tungsten cathodes.

Referring now to FIG. 3 there is shown an electrostatically focused klystron amplifier tube 13 incorporating the gridded electron gun of the present invention. More specifically, the electron gun 1 is disposed at one end of the tube for forming and projecting a beam of electrons axially to the tube 13 to a hollow beam collector structure 14 disposed at the terminal end of the beam path for collecting and dissipating the energy of the beam. A plurality of cavity resonators 15, 16, 17 and 18 are successively disposed along the beam path for electromagnetic interaction with the beam passable therethrough.

An input radio frequency signal to be amplified is applied to the first cavity 15 for exciting the electromagnetic fields thereof. The fields of the input cavity 15 serve to velocity-modulate the beam. The velocity modulation of the beam is converted into current density modulation in a subsequent field-free drift space 19 for exciting the fields of a buncher cavity 16. The excited fields of the buncher cavity interact on the electron stream to produce further velocity modulation and bunching thereof which is again amplified in the successive buncher cavity 17. The bunched electron beam excites the electromagnetic fields in the output cavity 18 and an output signal is extracted via an output coupler 21 and fed to a suitable load, not shown.

A plurality of ring-shaped electrostatic focusing lenses 22 are periodically disposed along the beam path for focusing the beam through the successive cavity resonators and drift spaces 19. Cathode potential is supplied to the focusing lenses 22 via leads 23.

In the electron gun assembly 1, a filamentary heater 24 heats the cathode emitter to its operating temperature. Filarment current for the heater 24 is derived from a power supply 25. Cathode potential for the emitter 2 is derived from a cathode power supply 26 which supplies a negative potential of approximately -6 kv with respect to ground for the cathode emitter 2. The accelerating anode 5 and the remaining body of the tube 13 is operated at ground potential. The control grid 7 is biased negative with respect to the cathode emitter 2 via a negative power supply 27 connected between the cathode 2 and the control grid 7. A secondary 28 of a pulse transformer 29 is connected in series with the circuit between the cathode emitter 2 and the control grid 7. A pulse generator 31 supplies a pulse to the primary 32 of the transformer 29 for pulsing the control grid 7 positive with respect to the cathode emitter 2 for initiating beam current.

Referring now to FIG. 4 there is shown an alternative tube structure incorporating features of the present invention. For the sake of explanation, the electron gun assembly 1 is only schematically indicated by cathode emitter 2 and control grid 7. In this embodiment, the accelerating anode 5 is formed by one magnetic pole of a beam focus solenoid 37. A second magnetic pole 35 is disposed adjacent the beam collector 14 and a cylindrical magnetically permeable yoke member 36 serves as a magnetic return path around the solenoid 37 which energizes the poles 5 and 35 respectively to produce an axially directed magnetic field between the poles 5 and 35 in the beam path for magnetically focusing the beam.

A conductive helix 38 coaxially surrounds the beam path in the region between the pole pieces 5 and 35 to form a R.F. wave supportive structure for cumulative electromagnetic interaction with the beam to produce amplification of R.F. wave energy applied to the helix 38. The signal to be amplified is applied to the helix at the upstream end 39 and the amplified output signals are extracted from the downstream end 41 of the helix. A vacuum envelope 42, as of glass, surrounds the helix 38 in the region between the poles 5 and 35.

The electron beam is generated in a region free of the magnetic field produced by the solenoid 37. The electron beam is accelerated through the control grid 7 and into the central aperture 4 of the accelerating electrode 5. As the beam enters the central aperture 4 of the accelerating electrode 5, it meets an axially directed beam focusing magnetic field which is adjusted to have the proper intensity to produce Brilloin focusing of the beam through the helical interaction of the magnetic fields. At the collector pole piece 35, the beam passes through the focusing magnetic field which is collected on pole structure 35 and the beam expands due to space charge effects and is collected on the interior surfaces of the beam collector 14.

Referring now to FIG. 5 there is shown an alternative tube embodiment incorporating features of the present invention. The tube of FIG. 5 is similar to that of FIG. 3 except that confined flow magnetic beam focusing is employed. More specifically, the magnetic beam focusing structure includes a centrally apertured anode pole piece 5 also forming the accelerating electrode 5 for the gun 1. A centrally apertured collector pole piece 45 is disposed adjacent the beam collector 14. A focus solenoid 46 is disposed between the two poles 5 and 45 for energizing of the magnetic poles 5 and 45. A cylindrically magnetically permeable yoke member 47 interconnects the two poles 5 and 45 outside of the solenoid 46 to provide a return flux path for the solenoid 46.

The anode pole piece 5 includes a cylindrical projection 48 which surrounds the cathode emitter 2. The cylindrical projection 48 cooperates with the anode pole piece 5 to produce a fringing magnetic field which threads through the cathode emitter 2 and converges through the central opening 4 in the accelerating electrode pole piece 5. The projection 48 and pole piece 5 are shaped so that the magnetic flux lines which pass through the cathode emitter 2 pass through the emitting surface 3 and converge through the anode aperture 4 along lines conforming to the desired trajectories for the electrons passing from the cathode emitter 2, grid 7 and aperture 4. An
exemplary line B in FIG. 5 illustrates the path followed by such magnetic flux lines. The electrons of the beam are con-
 fined by the magnetic field from the emitter 2 through the ac-
 celerating electrode 5 and between the poles 5 and 45 along the axis of the tube. The beam focus magnetic flux lines are col-
 lected on the collector pole piece 45 and the electrons leave the influence of the magnetic focusing field at the pole 45 and are subject to be uniformly collected over the interior surfaces of the beam collector electrode 14. 
A plurality of cavity resonators 51, 52, 53 and 54 are suc-
 cessively arranged along the beam path intermediate the pole pieces 5 and 45 for successive interaction with the electron beam to produce an amplified microwave output signal in the manner previously described in regard to the structure of FIG. 3. The input signal is coupled into the input resonator 51 via input coaxial line 55 and the amplified output signal is ex-
 tracted via output coupler and coaxial line 56. 
Referring now to FIG. 6 there is shown an alternative velocity modulated tube employing the gridded electron gun of the present invention. In this embodiment the gun 1 pro-
 jects a beam of electrons through the central aperture in the anode 5 and through the center of a helix wave supportive structure 38, previously described with regard to FIG. 4 to a beam collector electrode structure 14. A permanent magnet stack 61 is provided surrounding the beam path for focusing the beam through the helix 38. More specifically, the magnet stack 61 comprises a plurality of annular permanent magnets 62 axially polarized with adjacent magnets polarized in op-
 posite directions to produce a periodic axially directed mag-
 netic field in the beam path for focusing the beam in a conven-
tional periodic manner. Magnetically permeable annular mag-
 netic pole members 63 are disposed at the ends of the stack 61 and between adjacent magnets 62 for guiding the magnetic beam focusing flux through the beam path.
In operation R.F. signal energy to be amplified is applied to the helix structure 38 via input coupler 39. The wave energy on the wave supportive structure 38 cumulatively interacts with the electron beam, in the manner as previously described with regard to FIG. 4, to produce an output signal coupled via output coupler 41 to a load, not shown.
Referring now to FIG. 7 there is shown an alternative em-
 bodiment of the present invention. In this embodiment, the cathode emitter structure is substantially the same as that previously described with regard to FIG. 1 with the exception that a second multiapertured grid structure 65, which is sub-
 stantly identical to grid 7 is disposed substantially on or in the space of the cathode emitter 2 to inhibit migration of cathode material onto the island portions between adjacent emitting surfaces 3. Grid 65 operates at cathode potential and the weiblike members of the grid are in substantial registration with the similar weiblike members of grid 7. Such a grid 65 has become known in the art as a shadow grid and facilitates focusing of the electron beamlets through the individual apertures in the grid 7 thereby further reducing interception of the beam by the grid 7. Use of the shadow grid 65 provides less beam interception than a cathode structure of the type de-
picted in FIG. 1 which employs only grid 7. However, con-
 struction of a cathode emitter employing a shadow grid 65 is more difficult than fabricating a cathode and grid structure of FIG. 1. Thus, due to space 65 is typically employed only for extremely high power applications where beam interception must be reduced to an absolute minimum or in cases where grid current cannot be tolerated.
In this regard, oxide cathodes are used for short pulses, i.e., less than 20 microseconds, or for low current densities, i.e., 0.3, at long pulse and CW operation densities, i.e., 4 to 5.009/cm², under long pulse and CW opera-
tion, the dispenser cathode is employed. This type of cathode is also normally used for C-band and above where the small R.F. circuit size restricts the size of the beam and cathode. A dispenser cathode consists of a porous metallic button, typi-
cally tungsten, impregnated with electron emissive material, such as barium. Since emitting material is contained throughout the volume of the button, suppression of emission from the islands between adjacent lesser concave emitter por-
tions 6 is a more difficult task than that encountered with the oxide cathode since the pure nickel islands on the oxide coated cathode are largely nonemissive.
Referring now to FIGS. 8 and 9, there is shown an alterna-
tive embodiment of the present invention with means for sup-
pression of emission from the islands between adjacent lesser concave emitters 6 of a concave cathode dispenser 2. A barium-impregnated tungsten button having a concave surface 3 with a plurality of closely packed lesser hexagonal or circular and concave emitter surfaces 6 formed therein. A spherically concave multiapertured control grid 7 is spaced from the concave surface 3 with the apertures of the grid 7 being in registration with the lesser concave emitter portions 6, as aforesaid shadow grid 65, is incor-
porated in the surface 3 of the cathode 2 in noncontacting relation therewith. More particularly, a recess 67 is formed in the island portions of the emitter surface 3. The recess 67 has a pattern corresponding to the pattern of a normal projection of the control grid 7 onto the emitter surface 3. In a typical ex-
ample, the recess 67 is 0.005 inches deep and 0.016 inches wide. The walls of the grid 66, as of molybdenum, are 0.009 inches deep and 0.010 inches thick. The recess 67 is formed from its outer periphery via a relatively thick walled metallic tubular support 68 for supporting and heat sinking the grid 66. The grid 66 is spaced from the bottom and sidewalls of the recess 67, as by 0.001 inch and 0.003 inches, respectively. A portion 69 of the grid 66 protrudes over the surface 3 of the emitter 2 by, for example, 0.004 inches to serve as a focusing element to facilitate focusing of the electrons through the individual openings of the control grid 7. The second grid 66 is preferably coated with an electron emission-inhibiting materi-
al, such as carbon, zirconium, iridium or titanium.
Grid 66 is spaced from the cathode emitter 2 to impede the flow of heat from the cathode 2 to the grid 66 and to reduce migration of emissive material onto the grid. The grid 66 is operated at the same potential as the cathode 2. Support 68 is preferably cooled and made of a good thermally conductive material to facilitate cooling of the grid 66.
The cathode 2 is operated, in use, at between 900° and 1,100° C. At these temperatures, substantial grid emission can be obtained from grid structure close to the cathode, even when emission inhibiting coatings are employed. By cooling the second grid 66, by as little as 100° C. to 100° C., the cathode 2, grid emission can be greatly reduced. Heat sinking the grid 66 at the outer periphery reduces the temperature near the outer margin of the grid 66 where most of the grid emission would otherwise occur due to the largest area of the grid being located near the perimeter thereof. Heat shields 71 are preferably located between the outer periphery of the cathode 2 and the grid support structure 68 to further facilitate cooling of the grid 66 through the cooler support 68.
Referring now to FIGS. 10 and 11, there is shown an alter-
native embodiment of the present invention. The structure is essentially identical to that of FIGS. 8 and 9 except that the second grid 66 is supported in physical contact from the cathode emitter 2 by being brazed to the bottom wall of the recess 67 at 73. In this case, the heat sinking tubular support 68 for the grid 66 is omitted. The grid 66 is also coated with an electron emission-inhibiting coating, as aforesaid. A suitable braze alloy for making the brazed joint between grid 66 and the bottom wall of the recess is a conventional molyb-
denum - nickel or molybdenum - ruthenium mix. The braze is preformed and due to large current dispersive flows 66 and the porous tungsten body 2 after the tungsten body is impregnated with barium.
Although the electron gun of the present invention has been described in detail as employed in a number of different velocity modulated linear beam tubes it is also useful for other types of linear beam tubes such as, for example, convergent beam tetrodes, pentodes and triodes.
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Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

1 claim:

1. In a linear beam tube, means forming a thermionic cathode emitter having a concave-emitting surface generally approximating a figure of revolution, means forming an accelerating electrode structure having a central aperture of substantially smaller cross-sectional area than the area of the emitting surface of said cathode emitter such aperture being disposed in axial alignment with the axis of revolution of said concave-emitting surface of said cathode emitter for accelerating and converging a stream of electrons through its central aperture and into a unitary linear beam of electrons, means forming a multiapertured concave control grid structure disposed overlying the concave-emitting surface of said cathode emitter for controlling the electron current drawn through said accelerating electrode from said cathode emitter means, THE IMPROVEMENT WHEREIN; said concave emitting surface is constituted of a plurality of lesser individual concave cathode-emitting surfaces, said lesser surfaces being concave in each of two orthogonal directions, with radii of curvature substantially less than that of said composite cathode-emitting surface, individual ones of said lesser cathode-emitting surfaces having their centers in alignment along the convergent beam path with individual ones of the apertures in said multiapertured control grid to form a plurality of individual convergent beam electron guns projecting the beam through said control grid in a plurality of nonintercepting beamlets which converge into the unitary linear beam after passage through said control grid structure.

2. The apparatus of claim 1 wherein the tube is a velocity-modulated beam tube, and including means at the terminal end of the beam path for collecting and dissipating the energy of the beam, means forming a r.f. wave supportive structure disposed along the beam path intermediate said accelerating electrode structure and said collector electrode for velocity modulating the beam and for interaction with the velocity-modulated beam to produce an output r.f. signal.

3. The apparatus of claim 2 including means forming a magnetic beam focusing structure for producing an axially directed magnetic field in the linear beam path for focusing of the beam through said r.f. wave supportive structure.

4. The apparatus of claim 3 wherein said beam focusing magnetic structure produces a beam focusing magnetic field which also threads through the concave surface of said cathode emitter means for focusing the beam in the region of space between said cathode emitter and the central aperture in said accelerating electrode.

5. The apparatus of claim 1 including means forming nonemitting regions of said cathode emitter separating said individual ones of said concave emitters in the concave surface of said cathode emitter.

6. The apparatus of claim 1 wherein the apertures in said control grid are hexagonally shaped.

7. The apparatus of claim 5 wherein said means forming nonemitting regions of said cathode emitter include a second multiapertured grid structure substantially identical to said first grid structure and having its apertures in substantial alignment with the apertures in said first-mentioned multiapertured concave control grid to facilitate focusing of the individual beamlets through the apertures in said multiapertured control grid structure, said second multiapertured grid structure being disposed on the surface of said concave emitter and being adapted to operate at the same operating potential as said thermionic cathode emitter.

8. The apparatus of claim 1 wherein said concave emissive surface of said cathode is recessed in a pattern substantially conforming to the pattern of said multiapertured concave control grid, and a second multiapertured grid structure having a pattern conforming to the pattern of said control grid being incorporated in the recessed portion of the emissive surface of said cathode emitter.

9. The apparatus of claim 8 wherein said cathode emitter is a dispenser cathode having a porous metallic structure impregnated with an electron emissive material, and said second multiapertured grid structure is coated with an electron emission inhibiting coating.

10. The apparatus of claim 8 including, means for supporting said second grid structure from the outer periphery thereof, said second grid being disposed within said recessed portion of said cathode in spaced relation from the walls of said recessed portion to facilitate cooling of said second grid structure to reduce the temperature thereof relative to the temperature of said cathode emitter.

11. The apparatus of claim 10 wherein said second grid support means includes a tubular metallic structure coaxially disposed about said cathode emitter.

12. The apparatus of claim 8 including, means forming a metallic joint between at least one wall of said recessed portion of said cathode and said second grid structure for fixedly holding said second grid to said cathode emitter.