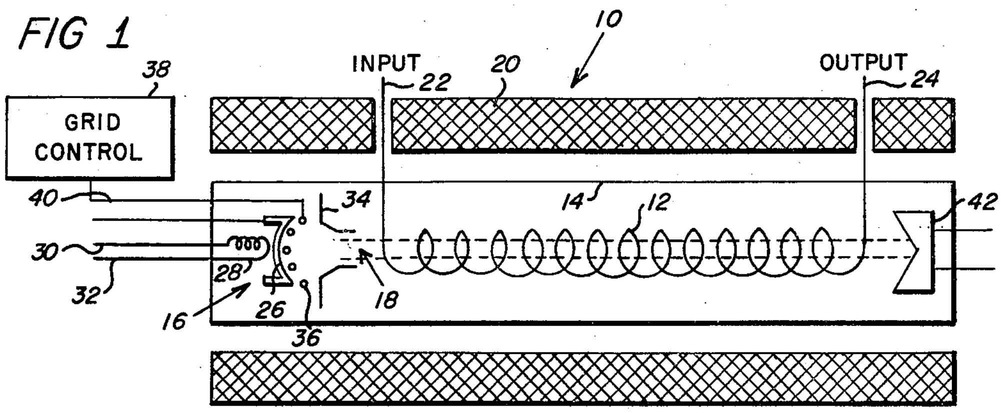
March 10, 1970 D. L. WINSOR 3,500,110

NONCURRENT INTERCEPTING ELECTRON BEAM CONTROL ELEMENT

Filed Aug. 23, 1967 3 Sheets-Sheet 1

FIG 1



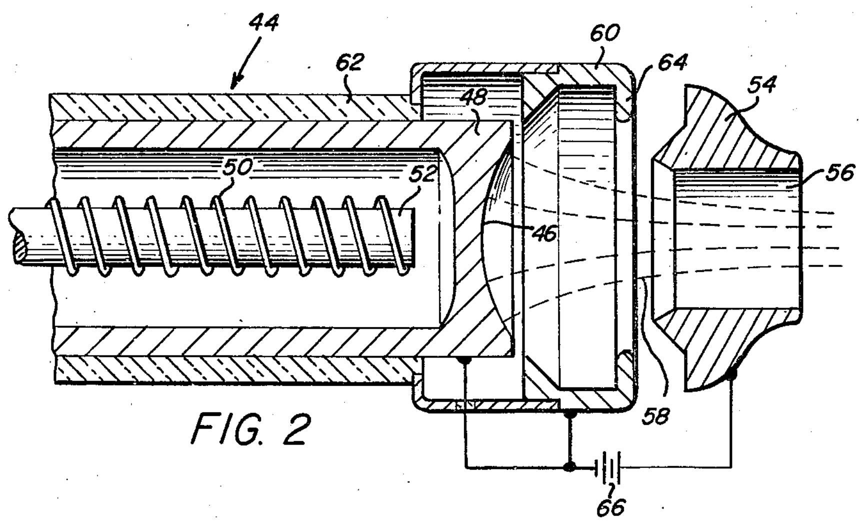
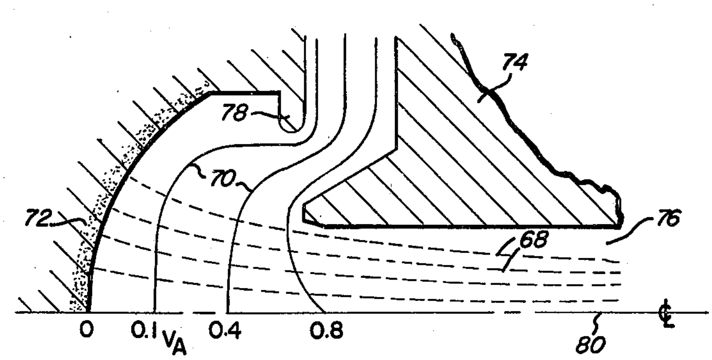




FIG. 2

FIG. 3

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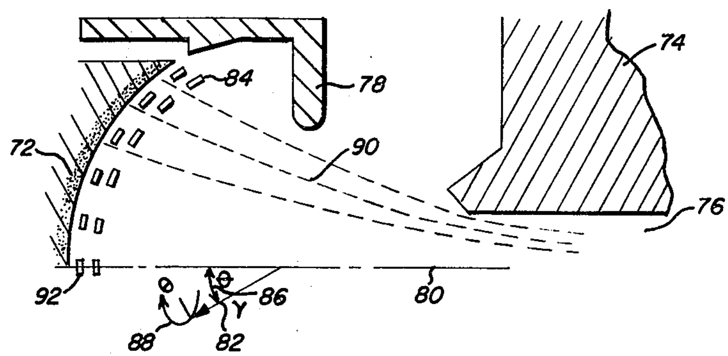


FIG. 4

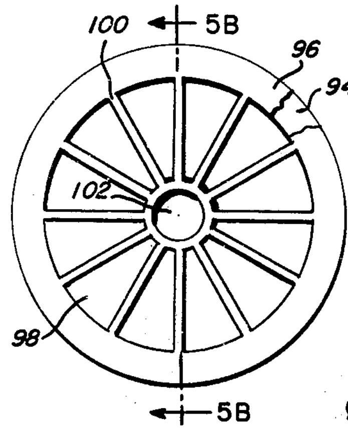


FIG 5A

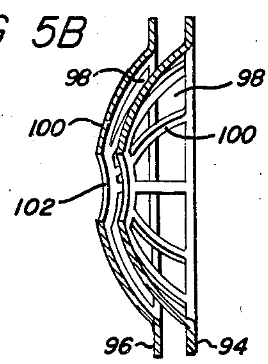


FIG 5B

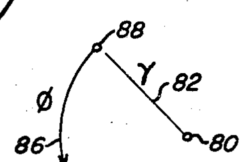


FIG. 6

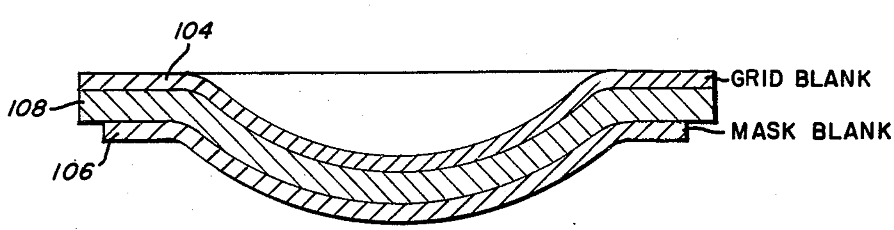


FIG. 7

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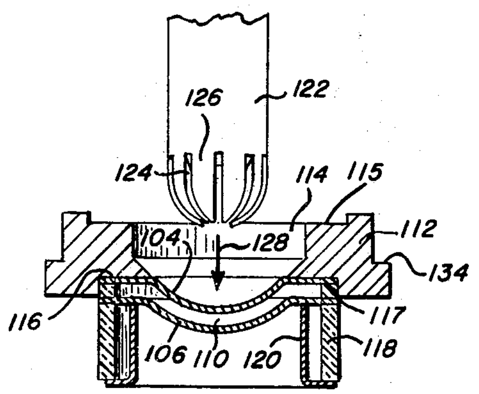


FIG. 8

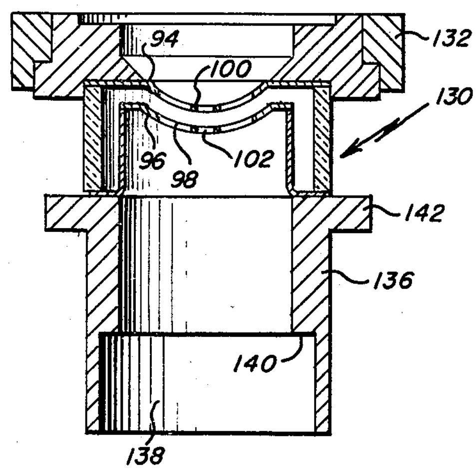


FIG 9

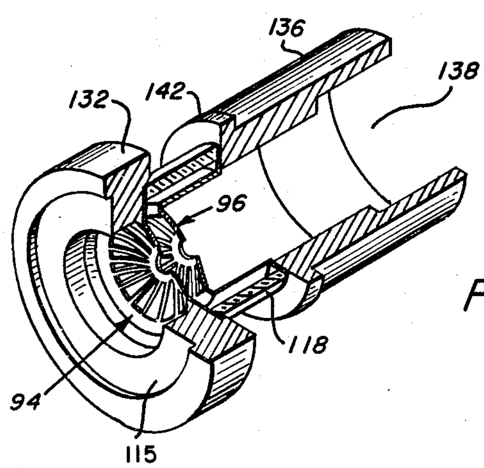


FIG. 10

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# United States Patent Office

3,500,110
Patented Mar. 10, 1970


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3,500,110


## NONCURRENT INTERCEPTING ELECTRON BEAM CONTROL ELEMENT


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Filed Aug. 23, 1967, Ser. No. 662,766
Int. Cl. H01j *25/34*
U.S. Cl. 315—3.5 5 Claims



### ABSTRACT OF THE DISCLOSURE

An electron transparent beam control structure including a grid electrode and shadow mask of such configuration that substantially ideal registration is attained to prevent any electrons emitted by a cathode electrode from impinging on the grid control element and consuming power. High perveance high convergence ratio Pierce type electron guns utilized in high power electron discharge devices are described as a selected illustrative embodiment of the invention.


### Background of the invention

Conventional klystron tubes and traveling wave devices having grid controlled electron gun emitters are continually being required to operate at higher and higher average power levels, which, in turn, requires substantially higher electron beam average power densities. Planar laminar flow type electron guns, as well as other type electron guns, may utilize control elements to assist in the modulation of the electron beam. Such elements are disposed in close proximity to the electron emitter and may comprise a grid-type electrode having an independently variable biasing voltage supply connected thereto with, desirably, a negative bias with respect to the emitter. When said bias is applied no beam current flows. The device is activated subsequently by application of a positive voltage to the grid electrode of an appropriate waveform, beam current flows and the device functions to amplify and produce output power. As said grid electrode is made positive in potential with respect to the emitting electrode, electrons are intercepted by the grid and power is consumed. As the grid electrode structure has a finite limit of power capable of being tolerated before destruction, the average power capability of the electron device is thereby limited.

Further, present day demands have led to the requirement for grid controlled electron beams having a current density far greater than the emitter emission densities. To achieve this goal the convergent Pierce-type electron beam gun has achieved wide usage. In such convergent guns the problem of introducing a grid electrode into the structure to permit beam modulation is rendered increasingly complex due to a requirement of conforming mechanically to electric potential configurations which may differ from regularly designed surfaces. Again, the electron flow into such grid electrodes often restricts the capabilities of the electron device in view of the fact that the grid electrode designed parameters cannot tolerate large input powers without degrading the optics of the resulting convergent electron beam.

Neutralizing means should desirably be provided adjacent to the electron emitter of the gun to offset the effects of a positively biased grid electrode element. Such a structure is often referred to in the art as a "shadow mask" and is biased at the emitter electrode potential. Perfect registry or alignment, however, of the mask and grid electrode is necessary, particularly in the convergent

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type gun where the spherical and radial aberrations of the electron beam must be carefully considered and the sitting of the mask and grid electrode is highly critical.

### Summary of the invention

In accordance with the teachings of the present invention a grid electrode and shadow mask arrangement to collectively define a control element is provided in such a manner that substantially all electrons emitted from the emitter electrode will pass through the control element without interception and restriction of the average power provided by the electron gun beam. A plurality of diaphragm members is rigidly secured together in a structure tailored to provide the final grid-mask spatial relationship in the over-all gun assembly. The unitary grid electrode and shadow mask assembly is provided with precisely aligned radially extending rib elements of any desired dimension by means of electrically actuated discharge machining of both the grid and mask element in one sequential operation by an accompanying tool bearing the final configuration of the resultant structure. In the spherical concave embodiment of a convergent electron gun, the grid and mask elements have differing curvatures of radius oriented to and concentrically disposed about a common point. Substantially ideal registry and alignment of the grid and shadow mask elements is thereby provided and biasing the first or mask element at the cathode potential permits operation of the grid element at a positive potential with negligible electron interception. Essentially zero power grid consumption is thus provided by the subject invention. While concave structures are disclosed and described herein, the invention is equally applicable to all grid electrode and mask structures of other well known configurations.

### Brief description of the drawings

The invention, as well as the details of the construction of a preferred illustrative embodiment, will be readily understood after consideration of the following detailed description and reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic representation of a prior art traveling wave electron discharge device;

FIG. 2 is an enlarged partial cross-sectional view of a prior art electron gun assembly of the convergent type;

FIG. 3 is a diagrammatic presentation of the equipotential planes and electron trajectories of an illustrative high convergence electron gun structure;

FIG. 4 is a schematic representation illustrative of the sitting of the grid and mask electrode elements in the non-uniform electric field configuration of a convergent electron gun wherein the $\theta$ as well as the $\phi$ trajectory components must be resolved;

FIGS. 5A and 5B are, respectively, front elevational and cross-sectional views of an illustrative grid-mask structure in accordance with the present invention;

FIG. 6 is a schematic view of the reference lines to assist in an explanation of the invention;

FIG. 7 is a cross-sectional view of a component of the over-all grid-mask assembly in one of the stages of fabrication;

FIG. 8 is an exploded view illustrative of the method of fabricating the illustrative embodiment of the invention;

FIG. 9 is a cross-sectional view of the completed machined grid-mask assembly components in one of the sub-assembly stages; and

FIG. 10 is a perspective view, partially broken away, showing the principal elements of the electron gun of the present invention.

Description of the preferred embodiment

Referring now to FIG. 1 of the drawings, a schmatic representation of a traveling wave tube embodiment is shown and designated **10**. A slow wave periodic electromagnetic energy propagating structure in the form of a helix **12** is aligned along the longitudinal axis of an envelope **14**. The wave propagating structure may, of course, assume any of the well known periodic structure configurations such as a ring and bar line, interdigital finger delay line, coupled cavity line, or a bifilar helix, as desired. The electron beam generation means **16** is disposed at one end of the tube envelope to propel and direct an electron beam designated collectively by the numeral **18**. Surrounding the over-all tube envelope is the magnetic field producing means **20**. A longitudinal magnetic field parallel to the path of the electron stream is provided by the magnetic means **20** which may comprise a permanent magnet or electromagnetic solenoid arangement. Microwave energy is coupled into and out of the respective ends of the slow wave structure by an input transmission line **22** and an output transmission line **24**.

The electron beam generation means **16** comprises an emissive cathode member **26** having an internal heater coil **28** with conventional leads **30** and **32** extending through the tube envelope for connection to an appropriate voltage supply. Anode member **34** is disposed in the intermediate region between the input end of the slow wave periodic structure and the electron beam generation means. This member is conventionally provided with a sufficiently high positive voltage to accelerate and direct the emitted electrons formed in a beam of the desired configuration along the interaction path adjacent to the slow wave structure. A grid control member **36** is disposed in close proximity to the emissive cathode member and is suitably biased by a voltage supply **38** connected by means of lead **40** to the grid electrode. The supply **38** may be varied from a negative to a positive biasing potential with respect to the cathode electrode. A collector electrode **42** is disposed adjacent to the opposing end of the envelope and provides a terminal for the electron beam traversing the longitudinal axis of the device.

In FIG. 2 a convergent electron gun assembly **44** is disclosed. In this configuration rather substantial thermal emission velocities are possible by means of a spherical concave emitting surface **46** at the outer end of cathode electrode member **48**. A heater coil **50** is supported on a rod member **52** to indirectly heat the emissive surface. In such electron gun structures an anode member **54** biased positively with respect to the cathode electrode adjacent to the emitting surface and provided with a central aperture **56** conforms and shapes the thermal electrons into a beam of reducing diameter represented by the numeral **58**.

To focus the beam to the diameter which is smaller than the over-all cathode emitting area, a beam-forming electrode **60** surrounds the emitting surface. This electrode creates a potential along the edge of the electron beam which desirably matches as nearly as possible the theoretical potential inside the beam. Ceramic member **62** supports the beam-forming electrode and inwardly extending diaphragm or lip **64** assists in exerting the constrictive forces on the electron beam. Generally the beam-forming electrode is biased at the cathode potential by the voltage supply means **66** also connected to the anode electrode **54**. The illustrative electron gun is referred to in the art as the Pierce electron gun. Appreciably high perveance which is defined as the ratio of total beam current to the three halves power of the beam voltage may be realized with this structure. Expressed in terms of amperes/volts values in the order of $5.9\times10^{-6}$ may be attained.

In FIG. 3 a theoretical calculated plot of the electron trajectories **68** and equi-potential planes **70** for a high convergence electron gun having an emitter surface **72**, anode electrode **74** with central aperture **76** and focusing element **78** is displayed. The lack of orthogonality is evident and is nearly always present in an electron gun which produces a well behaved resulting electron beam. This lack of orthogonal electron flow from the emitter surface makes the design and sitting of a nonelectron intercepting grid, other than as described herein, most difficult. The foregoing discussion points up the problems associated with the placement of a grid control element in close proximity to the emitter surface. FIG. 4, reference numerals relating to similar structure shown in FIG. 3 being similarly numbered, will now be referred to. Along the beam axis **80** the radius **82** and symbol $r$ indicates the radius of the emitter surface **72** from a focal point along the electron beam axis **80**. A honeycomb grid electrode disposed adjacent to the emitter surface illustratively comprising elements may utilize such elements provided in the $\phi$ plane **86** as well as the $\theta$ plane **88**. To achieve an ideal electron trajectory indicated by the dotted line **90** without any interception of the electron by the grid elements, a mask **92** would be required in an offsetting relationship to neutralize the force of the grid potential. Any grid-mask structure, therefore, will require complex calculations of the spatial relationship and each gun would have to be carefully individually tailored. The problem is further amplified by the fact that the critical spatial orientations must be maintained at the elevated temperatures at which the electron gun is conventionally operated. To achieve a practical grid electrode and mask structure the present invention teaches the provision of a substantially perfect registration of the grid-mask elements utilizing solely the $\phi$ directed elements which leads to the provision of a unitary structure in a spherical concave embodiment having a bursting sunrise effect when viewed in a front elevation.

Referring now to FIGS. 5A and 5B, a grid-mask assembly comprises two juxtapositioned diaphragms **94** and **96** having pie-shaped segmented openings **98** in each of the concave surfaces. Between each of the piece-shaped openings a radially extending rib element **100** is defined. Further, an aperture **102** may be provided in the composite grid-mask assembly through the technicque of fabrication. FIG. 6 explains the orientation of the rib elements with respect to the beam axis **80** and the spherical configuration along the plane referred to by the symbol $\phi$ and numeral **86** will be evident. The orthogonal axis **88** would have no grid elements disposed therealong.

In FIG. 7 an exemplary structure of solid diaphragm members **104** and **106** of a high temperature resistant metal such as, for example, molybdenum, is maintained in the desired shape during the forming operation to provide the spherical concave surface by member **108** of a relatively softer metal such as copper sandwiched between the diaphragms.

Other techniques for providing the desired grid-mask configuration prior to the fabrication of final assembly having the radial rib elements and segmented openings will be course be readily apparent to those skilled in the art. An example would be a stamping and die operation with careful control of the registry of the component parts. With the spherical concave embodiments differing curvatures of radius along the spherical surfaces will result since both members **104**, the grid blank, and **106**, the mask blank, have a common axis about which they are concentrically disposed. It is important in the teachings of the invention to bear in mind that throughout the manufacturing operation the uniform spatial relationship between the grid and mask be rigidly maintained by processing these components as an integral subassembly of the final over-all electron gun structure as will now be described.

In FIG. 8 the components of a suggested method of processing are illustrated. After shaping, the substantially rigid concave metallic diaphragms 104 and 106 are permanently secured, illustratively by brazing, to a cylindrical support member 112 which forms a permanent part of the over-all electron gun assembly. A space 110 between the diaphragms is maintained by ceramic spacers 117. A portion of the reentrant passageway 114 is utilized in the final assembly as the beam-forming electrode. To this end a circular lip member, not shown for the sake of clarity in the explanation of the present invention, would be secured to the outer planar surface 115 adjacent the end of the passageway 114 by the similar technique of brazing. The diaphragm members are joined within a recessed portion 116 disposed adjacent to the opposing end of the support member 112 and ceramic spacer members 117 and 118 form an integral part of this sub-assembly for providing electrical isolation of the grid members from the cathode member. In addition, an annular member 120 secures the lower diaphragm member 106 or what eventually will be considered the mask electrode in position. It is therefore evident that with the diaphragm members securely positioned and the fact that they are fabricated of a rather rigid metal such as molybdenum, it is now permissible to fabricate the diaphragm members as an integral unitary body to secure the final grid-mask structure illustrated in FIGS. 5A and 5B.

One method of fabricating the grid-mask components is the so-called electrical discharge machine or method which provides a highly intense arc to erode any metal disposed underneath the directed arc. In the practice of the invention, therefore, a tool or arc element 122 is provided with radially disposed notches 124 together with raised pie-shaped segmented portions 126 disposed therebetween. The notches 124 eventually define the rib elements 100, and the portions 126 provide for the erosion of the pie-shaped segments 98 between the respective radial rib elements. In an exemplary electrical discharge machine available commercially under the name Elox, a registered trade name, the tool element is a carbon composition and oil is disposed between this element and the component to be machined to provide for transmission of the high intense electrical arc. Travel of the tool element 122 in the direction indicated by the arrow 128 will cause the erosion of, successively, the diaphragm members 104 and 106 to thereby result in the desired grid electrode member 94 and the mask member 96.

Referring now to FIGS. 9 and 10 a still further evolution in the manufacture of the electron gun assembly in accordance with the practice of the present invention is noted. The subassembly heretofore described with reference to FIG. 8 has now been modified by the provision of the grid and mask elements 94 and 96 respectively, together with the central aperture 102 and rib elements 100. The subassembly designated generally by the numeral 130 has a further collar member 132 affixed to the shoulder 134 defined in the support member 112. In this illustration the cathode support member 136 having a passageway 138 defining a separate shoulder portion 140 and flange 142 is joined to the subassembly 130. Within passageway 138 the cathode electron emitter together with a heater coil is supported having a shape and construction closely similar to that shown in FIG. 2 and designated by numerals 46, 48, 50 and 52. Voltage biasing connections may be affixed to the member 136 at the cathode potential. The mask element 96 may also be biased at this potential. Grid electrode 94 is preferably biased through support member 112 at the slightly positive potential relative to the cathode for optimum convergence.

In accordance with the invention then substantially perfect alignment and registry may be assured in each structure by the simultaneous processing of the grid and mask elements as a common unitary unit. The teachings are equally applicable to any and all configurations of the grid and shadow mask elements including planar and circular as well as hollow beam electron guns. The transparency provided by the prevention of interception of electrons by the grid has now made possible grid control of electron beams of exceedingly high current densities having many kilowatts of average power. It will be evident to those skilled in the art that numerous modifications, alterations or variations may be practiced in the embodiments herein described. Accordingly, it is intended that any such modified embodiments be included within the scope and tenor of the invention as defined in the accompanying claims.



What is claimed is:

1. An electron gun assembly comprising:

an electron emissive cathode electrode for generating and projecting a converging beam of electrons along a predetermined axis;

a control electrode disposed along said axis in spaced apart relationship from said cathode electrode;

said control electrode defining a plurality of grid elements oriented in a predetermined manner;

a masking electrode intermediately disposed between said cathode and control electrodes and defining grid elements conforming to and in substantially identical registry with the elements in said control electrode;

said masking electrode being electrically biased at said cathode electrode potential.

2. An electron gun assembly according to claim 1 wherein said grid elements comprise a plurality of substantially rigid radially converging conductive members terminating in an apertured apex portion.

3. An electron gun assembly according to claim 1 wherein said control and second electrodes are of a substantially concave spherical configuration.

4. A traveling wave type electron discharge device comprising:

an envelope;

a periodic slow wave electromagnetic propagating structure disposed along the longitudinal axis of said envelope;

a high perveance high convergence ratio electron gun for producing a converging beam of electrons directed along the envelope axis adjacent to said slow wave structure;

said electron gun comprising an electrically biased electron emitting member;

a conductive masking member of spherical concave configuration positioned anterior to said emitting member and biased at a substantially similar electric potential as said electron gun;

said conductive masking member defining a plurality of radially disposed metallic elements with openings therebetween for passage of emitted electrons;

a grid control electrode of substantially identical configuration and positioned anterior to said conductive masking member and defining a plurality of substantially identical metallic elements in register with the underlying elements;

and input and output means for coupling electromagnetic energy to said slow wave structure for interaction with said electron beam.

5. In a high perveance high convergence ratio electron gun assembly adapted to produce a converging electron beam having an electron emissive surface, means for directing and projecting emitted electrons along a predetermined path comprising:

first and second conductive members of spherical concave configuration spaced apart a rigidly maintained uniform dimension and disposed with said first member nearest to said emissive surface;

said conductive members defining substantially identical grid elements with apertures therebetween for passage of electrons;

and means for electrically biasing the first conductive member at a potential whereby said second conductive member is substantially prevented from intercepting beam current from the emitting surface.


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U.S. Cl. X.R.

313—86

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(5/69)

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,500,110 Dated March 10, 1970

Inventor(s) Donald L. Winsor

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 2, delete "sitting" and insert -- siting --.

Column 2, line 51, delete "sitting" and insert --siting--.

Column 4, line 9, delete "sitting" and insert -- siting --.

Column 4, line 20, after the word "elements", first occurrence, insert -- 84 --.

Column 4, line 23, delete "electron" and insert -- electrons --

SIGNED AND
SEALED
NOV 3 1970

(SEAL)
Attest:

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Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents