July 24, 1962 E. J. COOK 3,046,442

HIGH PERVEANCE BEAM FORMING SYSTEM

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Fig. 2.

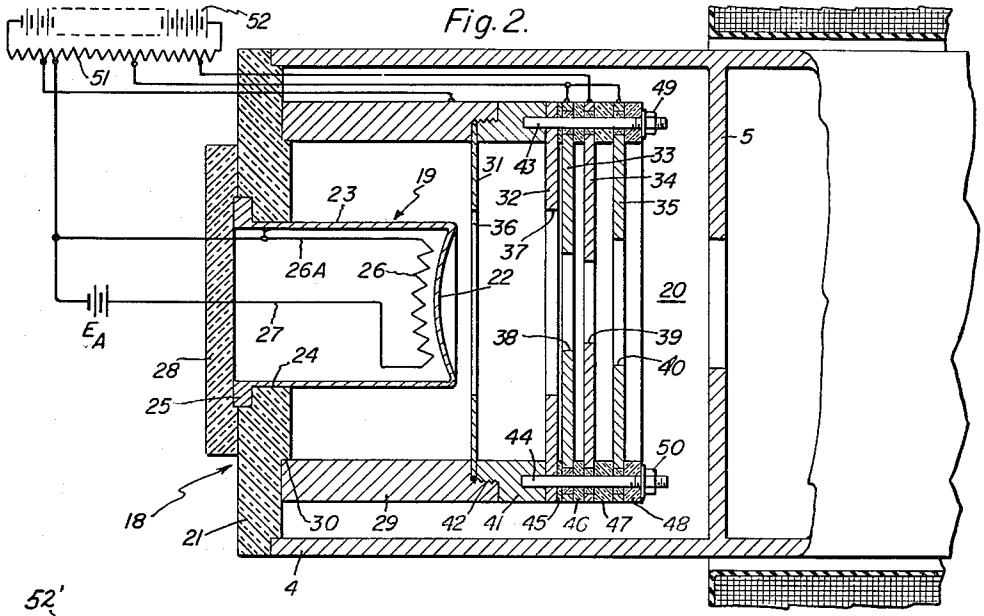


Fig. 3.

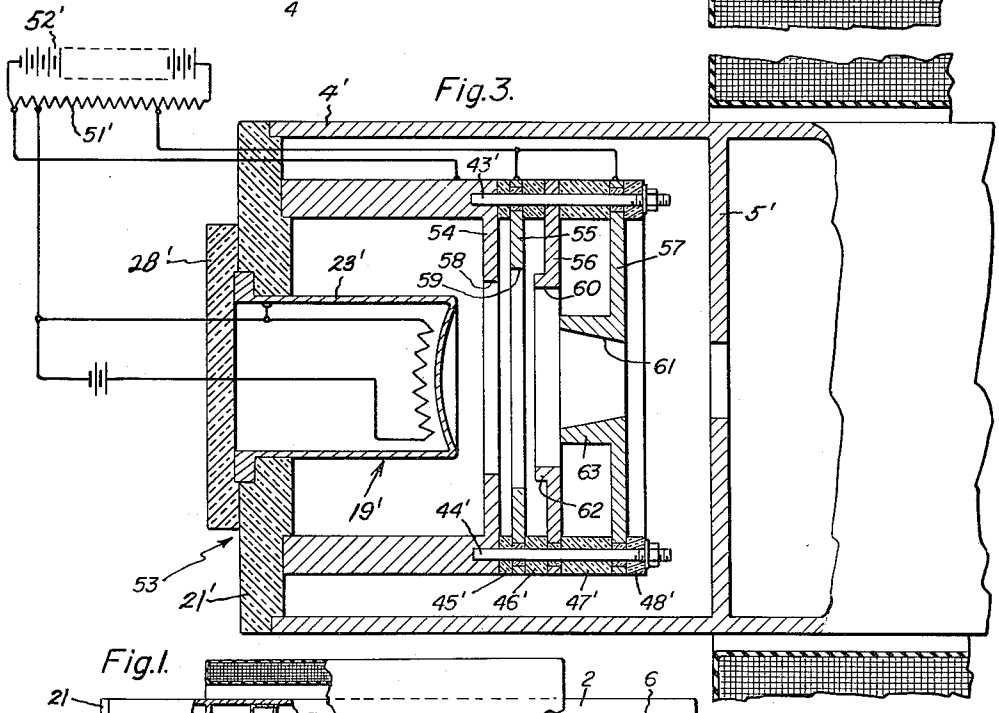
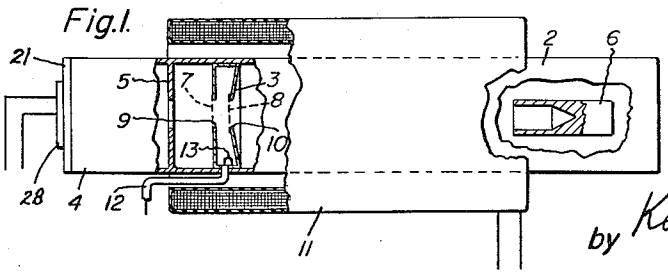


Fig. 1.



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HIGH PERVEANCE BEAM FORMING SYSTEM

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My invention relates to an electron tube device and more particularly to an electron gun utilizable for producing a pencil or narrow electron beam having high perveance properties.

For many electron tube functions, it is frequently desirable to utilize an electron beam having high values of perveance which is the quality of a beam defined as the ratio of the beam current to the three halves power of the electric potential producing the beam ($I/V^{3/2}$). A high beam perveance may be advantageously achieved by disposing an apertured anode of a tube near the tube cathode and applying a high positive potential to the anode with respect to the cathode. However, the usual effect of so positioning a highly, positively charged anode is to produce irregularity in the electric field in the interelectrode regions whereby non-uniform cathode loading occurs and the beam is subject to defocusing, distortion, aberrations and other adverse effects. Various techniques have been proposed for overcoming these undesirable effects but the prior apparatus required for accomplishing this result have been unduly complex and inflexible in their adaptability to various tube constructions.

It is accordingly a principal object of my invention to facilitate the production of an electron beam of high perveance that is not subject to defocusing, distortion, aberrations and other adverse effects.

In accordance with my invention, the above mentioned adverse effects in an electron beam of high perveance are avoided and uniform loading of the tube cathode is facilitated by subjecting the electrons emitted from the cathode to an electric field having imaginary concentric, spherical surfaces of equal potential value extending from the region of the spherically concave cathode where the radius of curvature of the field's equipotential surface is substantially equal to the radius of curvature of the cathode surface, to the anode. Such a field is produced by a novel construction and arrangement of accelerating electrodes between the cathode and the anode. The electrodes are of generally disc shape with central apertures aligned with each other and with the cathode and are spaced with respect to each other and have potentials applied thereto with respect to each other and with respect to the tube cathode so as to produce the concentric, spherical equipotential surfaces. Such spherical equipotential surfaces present uniform accelerating electric fields from the region of the cathode throughout the inter-electrode space to uniformly accelerate and converge the electrons to a narrow beam. The novel construction and disposition of the electrodes enables unusual uniformity in the field and thus, prevents aberrations and distortions therein.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which

FIGURE 1 illustrates a typical electron tube in which electron guns of the present invention are utilizable,

FIGURE 2 illustrates in cross-sectional elevation an electron gun in accordance with one embodiment of my invention, and

FIGURE 3 illustrates in cross-sectional elevation an electron gun in accordance with another embodiment of my invention.

The gun of my present invention is readily adaptable for use with various types of electron tubes. A typical tube of which the gun may form a component is a Klystron as shown generally at 1 in FIGURE 1 of the drawings. The tube 1 includes an evacuable tubular enclosure 2 in which may be mounted one or more beam interaction components, such as the resonant cavity 3. Since such further interaction components may be of known types and construction, a detailed description and showing thereof is not presented. The beam is produced by a gun enclosed in an enclosure 4 which has an apertured end wall 5 for accommodating the beam and passes through the tube 2 to be collected at the other end thereof remote from the gun, by a collector 6 which is maintained positive with respect to the cathode by suitable electrical connections. In traversing the tube 2, the beam passes through grids 7 and 8 extending across apertures 9 and 10 of resonator 3. For minimizing radial spreading of the beam as it passes along tube 2, a magnetic field extending axially along the tube 2 is produced by a solenoid 11 surrounding the effective length of the tube from wall 5 to collector 6 and for preventing interference with beam formation in the gun, the enclosure 4 and wall 5 are made of a suitable magnetizable material for shielding the gun from fields produced by solenoid 11.

For achieving beam-signal interaction, the cavity 3 may be excited by an input signal applied to a coaxial wave guide 12 having an inner conductor terminating in a loop 13 in the cavity and being connected to an inner wall of the cavity and a signal output may be taken from another of the interaction components, not shown, in a known manner.

Referring now to FIGURE 2 of the drawing for a detailed description of one embodiment of an electron gun according to my invention utilizable in the tube of FIGURE 1, 18 designates the gun in its entirety which includes a cathode electrode apparatus 19 and an anode and focusing electrode apparatus 20. Each of these electrode apparatus is mounted on and supported by an insulative end wall 21 sealed to and closing one end of magnetic shield 4 and are symmetrical about an axis extending from a central point of the cathode longitudinally along the gun.

For providing a source of electrons for the beam to be produced, cathode apparatus 19 includes a cathode 22 in the shape of a hollow spherical segment which is coated on the concave surface thereof with a suitable electron emission enhancing material. The cathode forms one end of a tubular member 23 which extends through an aperture 24 in wall 21. A flange 25 is formed at the end of tube 23 for engagement with a recess in wall 21 for proper axial and radial positioning of the tube 23 and cathode 22. The cathode surface 22 may be raised to electron emission temperatures by an electrical re-

sistance heater element 26 positioned adjacent to the convex surface of the cathode and the heater may be supplied with electrical energy through the wires 26A and 27 connected between respective ends of the heater element and respective terminals of a source of electrical energy represented by a battery E_A. To secure the tube 23 and to seal the interior thereof, an insulative backing plate 28 through which wires 26A and 27 pass, is sealed to the wall 21.

For mounting the anode and focusing apparatus 20, a conductive metal tubular anode supporting member 29 is secured to the interior surface of wall 21 as by a suitable metal to ceramic bond and for radially positioning the member 29, it is fitted on an annular shoulder 30 over which the tube end extends.

In accordance with my invention, an electric field having concentric, spherical, equipotential surfaces between cathode 22 and magnetic shield portion 5 is provided by a novel construction and arrangement of focusing electrodes 31 and 32, and anode electrodes 33, 34, and 35. These electrodes are apertured at 36, 37, 38, 39 and 40, respectively, and are perpendicular to the gun axis and therefore, parallel to each other. To facilitate mounting of electrode 31, member 29 is recessed at its end to accommodate the electrode 31 and for securing this electrode in place, a conductive, metallic extension member 41 is exteriorly threaded along a reduced portion 42 to engage an interiorly threaded portion of the recess in member 29.

Focusing electrode 32 and anode electrodes 33, 34 and 35 are mounted at the end of extension member 41 by a plurality of studs, two of which are shown at 43 and 44 securely embedded in one end of the member 41 and extending axially therefrom. The electrodes 32, 33, 34 and 35 are each provided with apertures near the periphery thereof to accommodate the studs and these apertures in anode electrodes 33, 34 and 35 are somewhat enlarged to allow the interposition of annular insulative members between the stud and these electrodes. Annular insulative members 45, 46 and 47, also apertured to accommodate the mounting studs are interposed between respective pairs of electrodes 32 and 33, 33 and 34, 34 and 35 and a similar annular insulative member 48 terminates the stack. To tighten these anode and focusing electrodes and insulating members, nuts, as shown at 49 and 50 threadedly engage the complementarily threaded ends of studs 43 and 44.

As a feature of my invention, to achieve the proper conditions for producing the desired field having concentric equipotential surface portions, the positioning of electrodes 31, 32, 33, 34 and 35 with respect to each other and with respect to cathode 22 and the sizes of apertures 36, 37, 38, 39 and 40 in these electrodes are interrelated in such a manner that in response to appropriate application of direct potentials to these electrodes, such a field is produced. The applied potentials are derived from taps on a resistive element 51 connected across a direct potential source represented by a battery 52. The relative dimensions and interrelationships between components and the potentials applicable thereto are determinable by electrolytic tank techniques.

Regarding the cathode as being at a reference potential of zero volts, anodes 33 and 35 are at the same high positive potential, V_A, with respect to the cathode, anode 34 is at a potential of $2V_A$ and focusing electrodes 31 and 32 are made negative with respect to the cathode such as by a potential of substantially $-.01V_A$. In accordance with my invention, the ratio of the potential of anode electrode 34 to V_A, the potential of electrodes 33 and 35 may be either greater or less than two, in which case, the electrodes are modified in size of aperture, spacing, etc. to accommodate such potential change and to maintain the field having spherical equipotentials. However, in this embodiment of my invention, for proper field formation, the aperture 37 is substantially the same

size as aperture 36 and is larger than any of the anode electrode apertures. Aperture 39 intermediate anode electrode 34 is smaller than apertures 38 and 40. With this construction, and with anode electrode 34 at a potential twice as great as the other anode electrodes, the anode electrodes produce the effect of an einzel lens in which the lens effect is converging rather than diverging as in conventional diode guns.

The field produced by the electrode arrangement has concentric equipotential surface portions extending from the cathode at which the radius of curvature of the equipotential surface portion is substantially equal to the radius of curvature of the cathode, to a point on the gun axis in the vicinity of the first anode aperture. The field configuration is therefore nearly radial in this critical area of the gun between the cathode and the anode electrodes where beam formation occurs.

In FIGURE 3 at 53 is illustrated another embodiment of gun according to my invention which is similar to the gun 18 of FIGURE 2 in certain respects and to simplify the description thereof, like parts are designated by the same numerals primed. In the gun 53, however, the anode and focusing apparatus is somewhat simplified over gun 18 in that only four electrodes are required which is one less than the number required in gun 18. Furthermore, only two different potentials rather than three are required. As in gun 18, one low negative potential is required but only one rather than two high positive potentials is required for the other electrodes enabling use of a simplified power supply apparatus.

The gun 53 comprises three disc shaped, focusing electrodes 54, 55 and 56 positioned substantially perpendicular to the tube axis and a generally disc shaped, anode electrode 57 also disposed substantially perpendicular to the tube axis. Anode electrode 57 is disposed on the side of the focusing electrodes remote from cathode 22.

The electrodes 54, 55, 56 and 57 are provided with respective apertures 58, 59, 60 and 61 to accommodate the electron beam and electrodes 56 and 57 are provided with respective lips 62 and 63, extending therefrom axially toward the cathode to aid in the field formation. Lip 63 which has the effect of increasing the electric field along the tube axis, is preferably tapered along the direction of the electric field formed so as to accommodate electron passage.

In the gun 53, for proper field formation, aperture 59 is greater than apertures in other electrodes and aperture 61 is smaller than the others. The potentials applied to electrodes 54, 55, 56 and 57 are taken from taps on resistor 51' and in accordance with a feature of my invention, anode electrode 57 and focusing electrode 55 have a predetermined positive potential V_A applied thereto. The focusing electrodes 54 and 56 have a negative potential of substantially $-.01V_A$ applied thereto. To facilitate such an application of potentials, electrode 55 is insulated from electrodes 54 and 56 by annular insulating spacers around the studs such as 43' and 44' and accommodated in peripherally located apertures in these electrodes and by annular insulating members 45' and 46'. Anode electrode is also insulated by insulative spacers around the studs and by annular insulative members 47' and 48'.

While the guns according to the two embodiments of my invention produce substantially the same type of field having concentric, spherical equipotential surface portions, the gun shown in FIGURE 3 has the advantage of fewer electrodes and requiring only one high positive direct potential rather than two, as required in the gun of FIGURE 2.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims

to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent is:

1. An electron beam forming system comprising a cathode in the shape of a hollow-spherical segment having an electron emissive coating on the concave surface thereof, an anode apparatus including a plurality of substantially parallel, apertured, disc shaped members, the apertures of said members being in alignment with each other and with the axis of said cathode, one of said members being disposed between a pair of further members and having an aperture smaller than the aperture in said further members, focusing electrode means including a disc parallel to said members and disposed between said anode electrode apparatus and said cathode and having an aperture aligned with the apertures in said members and being greater than any one of said apertures in said members, and means for applying high positive potentials to said members with respect to said cathode and a relatively low, negative potential to said focusing electrode with respect to said cathode, to establish an electric field between said cathode and anode apparatus having concentric, spherical equipotential surface sections.

2. An electron beam forming system comprising a cathode in the shape of a hollow-spherical segment having an electron emissive coating on the concave surface thereof, an anode apparatus including a plurality of spaced, substantially parallel, disc shaped, apertured members, and apertures of said members being in alignment with each other and with the axis of said cathode, an apertured focusing member including a disc parallel to said members and disposed between a pair of anode electrode members and spaced therefrom, said focusing member having its aperture in alignment with the other of said apertures, the anode electrode on the side of said focusing electrode remote from said cathode having an axial extension about the aperture therein and terminating in the proximity of a plane in the nearest portion of the focusing electrode, a further disc shaped focusing electrode having an aperture therein in alignment with the other of said apertures and being disposed between said cathode and said anode apparatus and means for applying a high potential, positive with respect to said cathode to said anode electrode members and a relatively low potential, negative with respect to said cathode, to said focusing electrode members whereby an electric field having concentric, spherical equipotential surfaces is formed between said cathode and said anode electrode, and having a radius of curvature substantially equal to the radius of curvature of said cathode in the region of said emissive coating.

3. An electron beam forming system comprising a cathode in the shape of a hollow spherical segment having an electron emissive coating on the concave surface thereof, an anode and focusing apparatus for producing an electric field having spherical equipotential surface sections between said cathode and said apparatus, said anode and focusing apparatus including a pair of substantially parallel, spaced and apertured, generally disc shaped members having their apertures in alignment with each other and with the axis of said cathode and a further apertured, generally disc shaped electrode parallel to said pair, the electrode of said plurality nearest to said cathode being a focusing electrode and the electrode the furthest from said cathode being an anode electrode and means for applying substantially the same high potential, positive with respect to the cathode to each of said pair of anode electrodes a different potential to said further electrodes and a low potential, negative with respect to the cathode to said focusing electrode.

4. An electron beam forming system comprising a cathode in the shape of a hollow spherical segment for emitting electrons from the concave surface thereof, an anode apparatus including a plurality of spaced, substantially parallel, apertured, disc shaped members, the apertures of said members being in alignment with each other and with the axis of said cathode, a first one of said members being nearer to said cathode than the others and a second of said anode electrodes being immediately adjacent to said first electrode, the aperture in said second electrode being smaller than the aperture in said first electrode, a pair of spaced, substantially parallel, apertured, disc shaped, focusing electrodes having apertures larger than the apertures in said members and being disposed parallel to and between said members and said cathode, the apertures of said focusing electrodes being concentric with the apertures in said members, means for applying a direct potential of a predetermined value, positive with respect to said cathode, to said first member and a direct, positive potential approximately equal to twice said predetermined value to said second member and means for applying a potential negative with respect to said cathode and approximately equal to .01 of said predetermined value to said focusing electrodes.

5. An electron beam forming system comprising a cathode in the shape of a hollow spherical segment, a pair of apertured, disc shaped focusing electrodes spaced from each other and from said cathode and having their apertures in axial alignment with the cathode, a plurality of disc-shaped, substantially parallel, apertured anode electrodes on the side of said focusing electrodes remote from said cathode and having their apertures in axial alignment with the said cathode, the aperture in a first anode electrode nearest to said focusing electrodes being smaller than the apertures in said focusing electrodes and larger than the aperture in a second anode electrode, a third anode electrode on the side of said second anode electrode remote from said cathode, whereby an electric field having concentric, spherical equipotential surface portions may be formed by applying a positive direct potential of predetermined value to said first and third anode electrodes, a positive direct potential of approximately twice said predetermined value to the second anode electrode and a negative direct potential of approximately .01 said predetermined value to said focusing electrodes.

6. An electron beam forming system comprising a cathode in the shape of a hollow spherical segment, an apertured, disc shaped focusing electrode spaced from said cathode and having its aperture in axial alignment with said cathode, an apertured, generally disc shaped anode electrode spaced from said focusing electrode on the side thereof remote from said cathode and having its aperture in axial alignment with said cathode, the aperture in said anode electrode being smaller than the aperture in said focusing electrode, means for applying a direct potential of predetermined value, positive with respect to said cathode to said anode electrode and a potential of substantially .01 of said predetermined value, negative with respect to said cathode to said focusing electrode to form an electric field between said cathode and said anode electrode having concentric, spherical equipotential surface portions.

7. An anode and focusing apparatus for an electron gun comprising a pair of spaced, apertured, generally disc shaped anode electrodes and a pair of spaced, apertured, generally disc shaped focusing electrodes, the apertures of said electrodes being in alignment, means for applying a potential of predetermined value and polarity with respect to a reference to each of said anode electrodes and a potential of approximately .01 of said predetermined value and a polarity opposite to said predetermined polarity to said focusing electrodes.

8. An electron beam forming system comprising a cathode in the shape of a hollow spherical segment, an apertured, disc-shaped focusing electrode axially spaced from said cathode and having its aperture in axial alignment with said cathode, an apertured, generally disc-

shaped anode electrode spaced from said focusing electrode on the side thereof remote from said cathode and having its aperture in axial alignment with said cathode, the aperture in said anode electrode being smaller than the aperture in said focusing electrode, means for applying a direct potential of predetermined value and polarity to said anode electrode and a potential of approximately .01 of said predetermined value and of polarity opposite to said predetermined polarity to said focusing electrode to form an electric field between said cathode and said anode electrode having concentric, spherical equipotential surface portions.

References Cited in the file of this patent

UNITED STATES PATENTS

2,202,631	Headrick	May 28, 1940
2,567,674	Linder	Sept. 11, 1951
2,888,605	Brewer	May 26, 1959
2,888,606	Beam	May 26, 1959