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L. F. BROADWAY ET AL
ELECTRON TUBE STRUCTURE FOR THE PRODUCTION
OF ANNULAR BEAMS OF ELECTRONS
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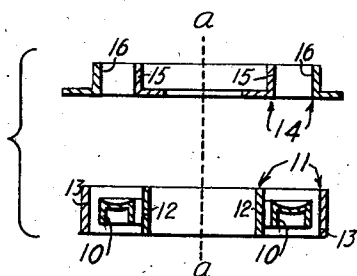


Fig. 1.

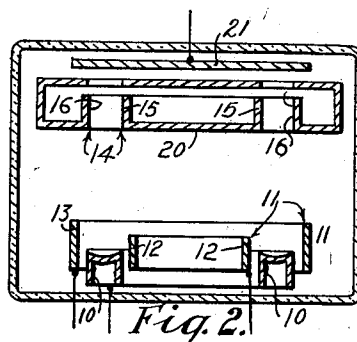


Fig. 2.

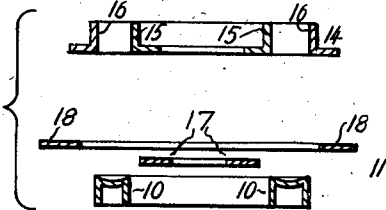


Fig. 3.

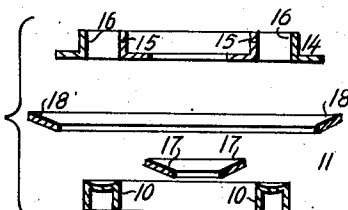


Fig. 4.

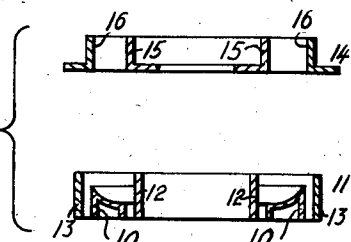


Fig. 5.

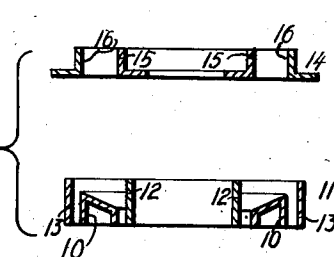


Fig. 6.

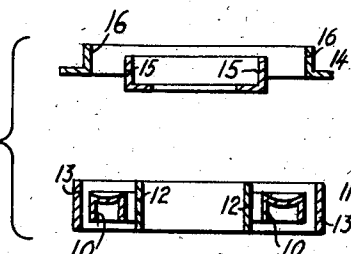


Fig. 7.

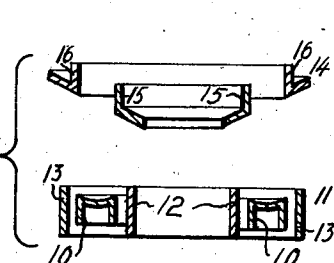


Fig. 8.

INVENTORS:
LEONARD FRANCIS BROADWAY
NORMAN CHARLES BARFORD
ALBERT FREDERICK PEARCE

BY:

H. G. Brown
ATTORNEY

UNITED STATES PATENT OFFICE

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ELECTRON TUBE STRUCTURE FOR THE
PRODUCTION OF ANNULAR BEAMS OF
ELECTRONS

Leonard Francis Broadway, Ickenham, Norman
Charles Barford, Southend, and Albert Fred-
erick Pearce, Hampton Hill, England, assignors
to Electric & Musical Industries Limited, Hayes,
England, a company of Great Britain

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This invention relates to the production of hollow beams of electrons.

In electron discharge devices of the velocity-modulation type it is sometimes necessary to employ hollow beams of electrons particularly where a beam is required for high powered devices. When employing circular hollow beams in such devices it is desirable that the mean diameter and cross-sectional area of the annulus should be constant along the length of the beam, but it is found, however, that owing to space-charge effects the mean diameter of the beam tends to increase as the beam proceeds from the cathode so that the general shape of the beam is of outwardly diverging conical form. Similar effects also arise in the case of hollow beams which have shapes other than a circular form in cross-section, such as an elliptical, square or rectangular cross-section. The term "annular" employed herein is intended to include these and other hollow shapes.

It is the object of the present invention to compensate for this outward spread in an annular beam of electrons.

According to one feature of the invention there is provided a circuit arrangement embodying an electron discharge device having means for generating an annular beam of electrons and having electrodes arranged internally and externally of said generated beam, said electrodes being maintained at such potentials as to produce an outwardly directed field which serves to compensate substantially wholly or in part for the outward spread in the said beam which would otherwise occur.

According to another feature of the invention there is provided an electron gun for generating an annular beam of electrons comprising an annular cathode, a cathode shield electrode means and accelerating electrode means when in the outer part of said cathode projects in the direction of the axis of the gun to an extent greater than the inner part of said cathode, the arrangement being such that if suitable operating potentials are applied to said gun the shape of said cathode introduces an outwardly-directed field which serves to compensate substantially wholly or in part for the outward spread in the generated beam which would otherwise occur.

According to another feature of the invention there is provided an electron gun for generating an annular beam of electrons comprising a cathode, a cathode shield electrode means comprising a pair of electrodes providing an annular space through which the generated beam is ar-

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ranged to pass, and accelerating electrode means, wherein the electrodes of said pair are asymmetrical with respect to the generatrix of said annular beam, the arrangement being such that if suitable operating potentials are applied to said gun said electrodes introduce an outwardly-directed field which serves to compensate substantially wholly or in part for the outward spread in the generated beam which would otherwise occur, the cathode being shaped, if desired, as above described.

According to yet a further feature of the invention there is provided an electron gun for generating an annular beam of electrons comprising a cathode, a cathode shield electrode means and accelerating electrode means comprising a pair of electrodes providing an annular space through which the generated beam is arranged to pass, wherein the electrodes of said pair are asymmetrical with respect to the generatrix of said annular beam, the arrangement being such that if suitable operating potentials are applied to said gun said electrodes introduce an outwardly-directed field which serves to compensate substantially wholly or in part for the outward spread in the generated beam which would otherwise occur, the cathode being shaped, if desired, as described above and the cathode shield electrode means being constructed, if desired, as described above.

In order that the said invention may be clearly understood and readily carried into effect it will now be more fully described with reference to the accompanying drawings, in which:

Figure 1 illustrates diagrammatically in longitudinal cross-section a known form of electron gun for producing an annular beam of electrons, and

Figures 2, 3, 4, 5, 6, 7 and 8 illustrate similar views of various embodiments of the invention for the purpose of producing an outwardly-directed electric field.

Referring first to Figure 1 of the drawings, the electron gun shown comprises a circular annular cathode 10 which is surrounded by annular cathode shield electrode means 11 which comprises a pair of concentrically arranged circular cylindrical electrodes 12 and 13 and an annular accelerating electrode means 14 which also comprises a pair of concentrically arranged circular cylindrical flanged electrodes 15 and 16. These electrodes are symmetrically arranged about the axis *a-a* and provide aligned annular spaces through which the beam passes. In operation the cathode 10 may be maintained at zero potential, the cathode shield means 11

at a negative potential and the accelerating means 14 at a positive potential. Where the arrangement is intended to produce an annular beam of electrons in a velocity-modulated electron discharge device the electrodes 15 and 16 constituting accelerating electrode means 14 may form part of the wall of the hollow resonator 20 employed in such a device, as shown in Figure 2, the annular space shown between the electrodes 15 and 16 forming an annular aperture through which the electrons pass into the hollow resonator and toward an electrode 21. It is found when employing an electrode construction similar to that shown in Figure 1 that space-charge effects tend to prevent the generation of an annular beam of electrons having a constant cross-sectional area and mean diameter throughout its length since such effects tend to cause the beam to spread outwardly between the electrode means 11 and 14 and impart to the electron beam a general shape in the form of an outwardly diverging cone having as its axis the axis $a-a$. The divergence of the inner surface of the beam towards the axis $a-a$ is negligible whilst the divergence of the outer surface of the beam away from the axis $a-a$ is substantial. In accordance with the invention, in order to overcome this spread in the electron beam an outwardly directed electric field is produced, i. e., a field directed away from the axis $a-a$. By suitable choice of such a field the mean diameter of the beam can be maintained more constant between the electrode means 11 and 14. This outwardly-directed field can be produced by maintaining the electrode 13 at a more negative potential than the electrode 12 or by maintaining the electrode 15 at a more positive potential than the electrode 16. The maintenance of the electrodes of the shield electrode means 11 and accelerating electrode means 14 at different potentials may be inconvenient in practice and, accordingly, it is preferred to produce the outwardly-directed field by making the cathode 10, the cathode shield electrode means 11 or the accelerating electrode means 14 asymmetrical in the manner hereinafter referred to. Several examples of guns according to the invention will now be described.

In Figure 2 of the drawings the cathode shield electrode means 11 is made asymmetrical with respect to the generatrix of the annular beam by making the inner electrode 12 shorter than the electrode 13 which has the effect, if these two electrodes are maintained at the same potential, of producing an outwardly-directed field to compensate for the outward spread of the electron beam. Typical dimensions of the cathode and the cathode shield electrode means 11 may be as follows. The diameter of the electrode 12, 33 mms., the inner diameter of the annular cathode, 35 mms., the outer diameter of the annular cathode, 41 mms., and the diameter of the electrode 13, 43 mms. The emitting surface of the cathode shown in Figure 2 is concave and has a radius of curvature of 5 mms., the electrode 13 projects above the peripheral edges of the cathode a distance of 2.5 mms., whilst the electrode 12 projects above the peripheral edges of the cathode a distance of 2 mms.

In Figure 3 of the drawings the cathode shield electrode means 11 comprises a pair of concentric rings 17 and 18 and the asymmetry with respect to the generatrix of the annular beam is introduced by disposing these rings, however, in differ-

ent planes with the ring 17 nearer to the cathode 10. In Figure 4 the rings 17 and 18 instead of being arranged in planes are arranged to conform to the surface of a wide-angled cone.

In the example shown in Figure 5 of the drawings, asymmetry is introduced in the cathode, the outer part of the cathode 10 projecting in the direction of the axis of the gun to a greater extent than the inner part, as shown. The cathode in this figure is still concave although, if desired, the emitting surface of the cathode may be flat in cross-section and may conform to the surface of a wide-angled cone, as shown in Figure 6.

In the example of the invention shown in Figure 7, the accelerating electrode means 14 is asymmetrical with respect to the generatrix of the annular beam, the electrode 15 of the accelerating electrode means being disposed closer to the cathode 10 compared with the electrode 16, as shown, whilst in Figure 8 a similar arrangement is adapted with the exception that the flanges of the electrodes 15 and 16 are arranged to conform to the surface of a wide-angled cone, as shown.

Although in Figures 1, 2, 3, 4, 7 and 8 the cathode illustrated has a concave-emitting surface, it will be understood that this surface may, if desired, be flat or of any other suitable shape.

In some cases it may be desirable to make the mean diameter of the annular aperture in the electrodes 15 and 16 slightly smaller than the mean diameter of the annular cathode 10.

It will be appreciated that the invention is not limited to the production of annular beams of circular form in cross-section, since it is equally applicable to the production of annular beams of elliptical, square, rectangular or other hollow shapes. The electrodes of the guns used for generating such beams will be similar in longitudinal section to the section of the electrodes shown in Figures 2 to 8 but in elevation the shape of the cathode and the shape of the electrodes 12, 13, 15 and 16 will be such as to conform to the shape of the beam it is desired to generate.

The invention can also be applied to guns designed to produce a rectilinear flow of electrons as described in the Journal of Applied Physics vol. II August 1940, page 548 and British patent specification No. 545,835. Where the invention is applied to the cathode shield electrode means of such a gun the asymmetry with respect to the generatrix of the annular beam can be introduced by making the angular position of one electrode of said shield electrode means relative to the generatrix of the annular beam different from the other electrode. Where the invention is applied to the accelerating electrode means, one electrode of said means will be differently shaped compared with the other electrode.

Although in the above examples of the invention various constructions are shown for producing an outwardly-directed field, it will be understood that, if desired, a combination of these constructions may be employed. Also different potentials may be applied to the individual electrodes 12, 13 and 15, 16 of Figures 2 to 8 for the purpose of assisting in the production of the outwardly-directed field. Further the invention is not limited in its application to electron discharge devices of the velocity-modulation type.

What we claim is:

1. An electron gun for generating an annular

beam of electrons comprising an annular cathode, an annular accelerating electrode means spaced from and axially aligned with said cathode to define an annular beam path therebetween, and an annular shield electrode means coaxially disposed adjacent said cathode, one of said cathode and said shield electrode means including inner and outer annular parts located on opposite sides of said annular beam path in the region extending from said accelerating electrode means to and including said cathode, said parts being asymmetrical with respect to the generatrix of said annular beam, whereby an outwardly-directed electric field will be established across said annular beam during operation of said electron gun for preventing spreading of said annular beam.

2. An electron gun according to claim 1, wherein said parts are separate elements having separate terminals for maintaining said inner part at a higher potential than said outer part to assist said asymmetrical arrangement in establishing said outwardly-directed electric field.

3. An electron discharge device comprising an annular cathode electrode means for generating an annular beam of electrons, an annular shield electrode means adjacent to said cathode electrode means, and a hollow resonator spaced from said cathode electrode means and having a wall provided with an annular aperture axially aligned with said annular cathode and shield electrode means, the portions of said wall adjacent the inner and outer boundaries of said annular aperture constituting an annular accelerating electrode means for said beam, one of said electrode means being asymmetrical with respect to the generatrix of said beam, whereby a radial electric field will be established across the beam path during operation of said device, for preventing outward spreading of said annular beam.

4. An electron gun for generating an annular beam of electrons comprising an annular cathode and an annular accelerating electrode means spaced from and axially aligned with each other to define an annular beam path therebetween, and an annular shield electrode means coaxially disposed adjacent said cathode, one of said cathode and said shield electrode means including inner and outer annular parts located on opposite sides of said annular beam path in the region extending from said accelerating electrode means to and including said cathode, said inner electrode being spaced from said accelerating electrode means a greater distance than said outer part, whereby an outwardly-directed electric field will be established across said annular beam during operation of said electron gun, for preventing spreading of said annular beam.

5. An electron gun according to claim 4, wherein the outer part of said cathode projects toward said accelerating electrode means to a greater extent than its inner part, to establish said outwardly-directed electric field.

6. An electron gun for generating an annular beam of electrons comprising an annular cathode and an annular accelerating electrode means spaced from and axially aligned with each other to define an annular beam path therebetween, and an annular shield electrode means coaxially disposed adjacent said cathode, said shield electrode means including inner and outer annular parts located on opposite sides of said annular beam path in the region extending from said accelerating electrode means to and including said cathode, said inner part being spaced from said accelerating electrode means a greater distance

than said outer part, whereby an outwardly-directed electric field will be established across said annular beam during operation of said electron gun, for preventing spreading of said annular beam.

7. An electron gun for generating an annular beam of electrons comprising an annular cathode, an annular accelerating electrode means spaced from and axially aligned with said cathode, and an annular shield electrode means coaxially disposed between said cathode and accelerating electrode means and including a first ring of diameter smaller than said cathode and a second ring of diameter larger than said cathode, said first ring being spaced from said accelerating electrode means a greater distance than said second ring, whereby an outwardly-directed electric field will be established across said annular beam during operation of said electron gun, for preventing spreading of said annular beam.

8. An electron gun for generating an annular beam of electrons comprising an annular cathode and an annular accelerating electrode means spaced from and axially aligned with each other to define an annular beam path therebetween, and an annular shield electrode means coaxially disposed adjacent to said cathode, each of said electrode means including inner and outer annular parts located on opposite sides of said annular beam path, at least a portion of each of said parts of said shield electrode means being located between said cathode and said accelerating electrode means, the spacing between the inner parts of said electrode means being different from the spacing between the outer parts thereof, whereby an outwardly-directed electric field will be established across said annular beam during operation of said electron gun, for preventing spreading of said annular beam.

9. An electron gun according to claim 8, wherein said parts of at least one of said electrode means are separate elements having separate terminals for maintaining said inner part at a higher potential than said outer part, to assist said different spacing in establishing said outwardly-directed electric field.

10. An electron gun according to claim 8, wherein the spacing between said inner parts is greater than the spacing between said outer parts.

11. An electron gun according to claim 8, wherein the spacing between said inner parts is less than the spacing between said outer parts.

LEONARD FRANCIS BROADWAY.
NORMAN CHARLES BARFORD.
ALBERT FREDERICK PEARCE.

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