

July 7, 1964

KERN K. N. CHANG
ELECTRON TUBE GENERATING OPPOSITELY DIRECTED
RADIALLY-DISPLACED BEAMS
Filed Jan. 3, 1961

3,140,420

Fig. 1.

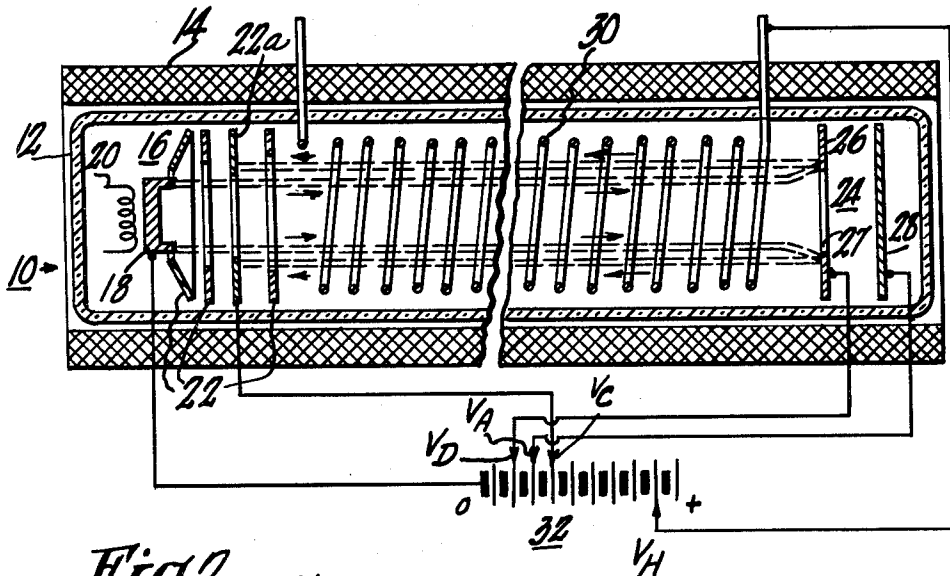


Fig. 2.

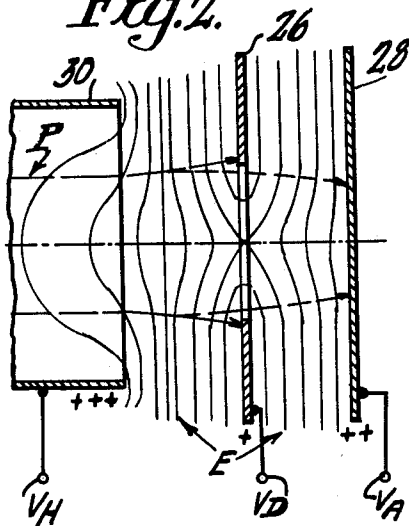
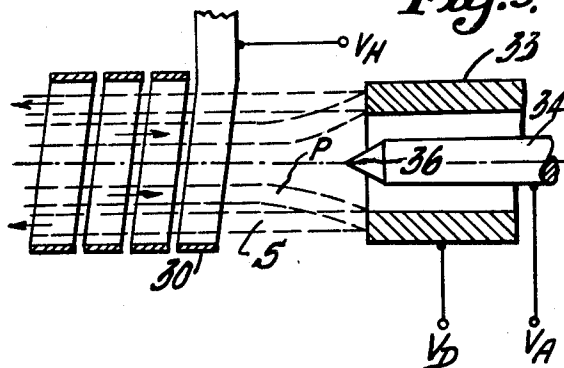


Fig. 3.



INVENTOR.
Kern K. N. Chang
BY *Thomas R. Webb*
AGENT

1

3,140,420

ELECTRON TUBE GENERATING OPPOSITELY DIRECTED RADIALLY-DISPLACED BEAMS

Kern K. N. Chang, Princeton, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Filed Jan. 3, 1961, Ser. No. 80,233

6 Claims. (Cl. 315—3.6)

The present invention relates to plural beam electron tubes and particularly to new and improved means for producing two distinct oppositely-directed electron beams of different velocity.

As a result of the development of backward wave amplifiers and oscillators, plasma oscillators, reflex klystrons, etc., the need has arisen for an efficient means for producing two oppositely-directed electron beams of different velocity for interaction with each other or with a circuit element, such as a traveling wave helix or a cavity resonator. In such an arrangement it is usually necessary or desirable that the paths of the two beams be physically displaced from each other to avoid interference therebetween.

In the usual reflex klystron, an electron beam is projected through a cavity resonator, where it is velocity modulated by a high frequency signal, toward a reflector electrode maintained at a potential below that of the cathode, so that the electrons instead of being collected there are reflected back through the cavity resonator wherein they induce high frequency fields and are collected. In some reflex klystrons, means are provided to direct the reflected electrons back along paths displaced from their forward paths. However, the velocity of the reflected electrons through the klystron resonator is the same as their original forward velocity therethrough, because the velocity in each direction is determined by the difference between the potentials of the resonator and the cathode from which the electrons were emitted.

Arrangements have been proposed wherein two oppositely-directed beams are projected independently by two separate electron guns located at opposite ends of the interaction space. These, of course, require separate cathode and cathode heating means, which add to the complexity of the tube.

German Patent 836,816 discloses an arrangement for producing two oppositely-directed beams comprising a primary electron gun at one end of an interaction helix and a central collector at the other end adapted to produce secondary electrons which travel back through the interaction helix intermixed with the primary electrons. The tube is provided with a ring collector surrounding the beam path in front of the central collector and a magnetic focusing solenoid extending from the electron gun to the two collectors. The ring collector is biased at a potential much higher than the central collector, which, together with the fringing magnetic field at the collectors, causes the primary beam to diverge so that part of it is collected by the ring collector and part by central collector. In addition to the interference between the primary and secondary beams in this arrangement, it is impractical to control the current and velocity of the secondary beam independently. Varying the potential of the secondary electron source (the central collector) will vary both the current and the velocity of the secondary beam. Impractically large changes in the high potential of the ring collector would be required to produce substantial changes in the secondary beam current.

An object of the present invention is to provide a simple means for producing two distinct oppositely-directed electron beams of different velocity.

2

In accordance with the invention, a focused primary electron beam of given diameter is projected from a thermionic cathode in one end of an elongated envelope through a hollow drift space electrode to a collector structure in the other end of the envelope comprising a secondary emissive electrode or dynode having a central aperture of larger diameter than the beam. At least the major part of the primary beam is caused to diverge or de-focus outwardly and impinge upon the dynode around the aperture therein. The dynode is biased at a potential lower than the drift space electrode in order to accelerate secondary electrons from the dynode through the drift space as a hollow beam surrounding and spaced outwardly from the primary beam. Preferably, an auxiliary electrode is positioned near the apertured dynode and varied in potential to vary the beam current of the secondary beam. The desired beam velocity of the secondary beam is obtained by adjusting the potential of the dynode relative to the potential of the drift space electrode. The primary beam is preferably hollow.

In the accompanying drawing:

FIG. 1 is an axial sectional view of a plural beam electron tube embodying the present invention;

FIG. 2 is an enlarged axial sectional detail view of the collector portion of the tube shown in FIG. 1; and

FIG. 3 is a view similar to FIG. 2 of a modification thereof.

In the embodiment of the invention illustrated in FIGS. 1 and 2, the numeral 10 designates an electron beam tube having an elongated envelope 12 surrounded by an axial magnetic focusing solenoid 14. An electron gun structure 16, comprising an annular thermionic cathode 18, a cathode heater 20 and several beam-forming electrodes 22, is coaxially mounted in one end of the envelope 12 to project a hollow primary electron beam of given diameter, beam current and beam velocity to a collector electrode structure 24 in the other end of the envelope. Collector structure 24 comprises a secondary emissive electrode or dynode 26 in the form of a metal plate having an aperture 27, of larger diameter than the primary beam, coaxial with the tube axis, and an auxiliary electrode 28 in the form of a metal plate extending across the axis in a plane beyond the dynode 26. A conductive means, such as a traveling wave tube helix 30, of larger inside diameter than the dynode aperture 27, is coaxially disposed between the electron gun 16 and collector structure 24 to form an interaction drift space. One of the gun electrodes, 22a, having an aperture diameter approximately equal to the diameter of the dynode aperture 26a, serves as a collector for most of the secondary electrons emitted by the dynode 26.

In the operation of the electron beam tube of FIGS. 1 and 2, the various electrodes are connected by external leads to a suitable D.C. voltage source 32 to apply positive potentials including V_H to the helix 30, V_D to the dynode 26, V_A to the auxiliary electrode 28, and V_C to the collector 22a, relative to the cathode. The highest potential is V_H , which determines the primary beam velocity in the interaction space. The potential, V_D , of the dynode 26 is adjusted to produce the desired secondary beam velocity, determined by $V_H - V_D$. The potential, V_A , of electrode 28 is adjusted to vary the electric field pattern E of the three electrodes 30, 26 and 28. This field, as shown in FIG. 2, is a composite of the right half of FIG. 13.14 with the left half of FIG. 13.16, on pages 347 and 348 of the textbook "Vacuum Tubes," by Spangenberg, McGraw-Hill, 1948. Preferably, V_A is somewhat higher than V_D to prevent secondary electrons from the auxiliary electrode 28 from going to the dynode 26. Un-

der these conditions, the electric field associated with the three electrodes tends to converge the primary beam P towards the central axis, as indicated by the short-dash lines in FIG. 2. However, this converging force is opposed by the de-focusing effects of the space charge of the primary beam itself in the region between the helix 30 and the dynode 26 where the beam is sharply decelerated, with the result that the primary beam is caused to diverge outwardly in that region sufficiently that at least a major portion thereof impinges on the surface of dynode 26 around the aperture 27, as shown by the long-dash lines in FIG. 2. Changing the potential, V_A , of electrode 28 changes the electric field pattern E, which changes the fraction of the primary beam reaching the dynode, thereby changing the number of secondary electrons emitted. In general, raising V_A strengthens the convergent effect of the lens field E, thus reducing the divergence of the primary beam. On the other hand, if V_A is sufficiently negative relative to V_D , the lens field will be divergent. It will be understood that, for a given field pattern E, the degree of divergence of the primary beam due to space charge effects is dependent upon the primary beam current density.

The strength of the focusing magnetic field of solenoid 14 is sufficient to prevent substantial de-focusing of the primary beam prior to entering the decelerating region between the helix 30 and dynode 26. The magnetic field also substantially confines the secondary electrons to a hollow cylindrical beam path displaced outwardly from the primary beam path throughout their entire travel through the helix 30 to the collector 22a, thus avoiding intermixing of the primary and secondary beams in the interaction space.

FIG. 3 shows a different embodiment of the invention, wherein the plate electrodes 26 and 28 of FIG. 1 are replaced by a hollow cylindrical dynode 33 and a central rod 34, respectively. The end 36 of the rod 34 facing the primary beam P is tapered to correspond roughly to the shape of the intersecting equipotential lines of the field E of FIG. 2, and potential V_A is made substantially equal to the potential of those lines, which is nearer V_D than V_A in FIG. 2. Under these conditions, the potential of the rod 34 establishes substantially the same field E as the higher potential of the plate 28 in FIG. 2, for the same V_H and V_D .

As an example only, an experimental tube incorporating substantially the structure of FIG. 1 modified as shown in FIG. 3 was constructed with a 5 x 25 mils tape helix, 35 t.p.i., 100 mils inside diameter (I.D.); a dynode of gold-plated stainless steel, 60 mils I.D., 100 mils O.D., 380 mils length; a gold-plated stainless steel rod, 26 mils O.D., 60° taper, 660 mils length; an oxide-coated primary cathode, 25 mils I.D., 50 mils O.D.; a secondary electron collector, 60 mils I.D.; 80 mils (minimum) distance between the helix and the dynode; and the pointed end of the rod extending 13 mils beyond the dynode.

Table I is a record of certain tests that were made on this experimental tube with different applied potentials:

Table I

V_C	V_H	V_D	V_A	I_C	I_H	I_D	I_A
(in volts)				(in micro amperes)			
55	300	50	55	140	50	280	30
150	400	100	110	200	50	210	40
250	600	200	220	300	50	140	10

In this series of tests, V_D was increased by increments to vary the impact velocity of primaries at the dynode 26, V_H was increased by greater increments than V_D to increase the secondary electron velocity, and V_A and V_C were kept higher than V_D .

Table II comprise values calculated from Table I:

Table II

$V_H - V_D$	$V_A - V_D$	$V_H - V_A$	$I_S = I_C + I_H$	$I_S + I_D$	$I_P = I_S + I_D + I_A$	δ
250	5	245	190	470	500	.403
300	10	290	250	460	500	.53
400	20	380	350	490	500	.71

In Table II, it is assumed that all of the primary electrons are collected by either the dynode or the rod collector, that all secondaries from the rod return to it, and all secondaries from the dynode are collected by either the helix or the secondary electron collector, in which case I_P is the primary beam current, I_S is the secondary beam current, and δ , the secondary emissive ratio of the dynode, would be equal to I_S divided by $I_P - I_A$. The variation in δ is, of course, due to the variation in primary electron impact velocity, determined by V_D . While the above assumptions may not all be correct, the tests clearly showed that the primary beam could be diverged, in accordance with the invention, in opposition to the convergent lens and the focusing field, to produce satisfactory secondary beam currents radially displaced from and oppositely directed with respect to the primary beam.

It will be understood that the primary and secondary beams may be focused by means other than a solenoid, such as a periodic electrostatic beam focusing system.

What is claimed is:

1. Means for producing two oppositely-directed radially-displaced electron beams of different velocity, comprising an elongated envelope having a longitudinal axis, an electron gun in one end of said envelope for projecting a cylindrical primary beam of given diameter along said axis, electrode means in the opposite end of said envelope for collecting said primary beam comprising a dynode having an aperture of larger diameter than said primary beam coaxial with said axis, hollow conductive means forming a drift space between said electron gun and said dynode, means for biasing said dynode at a lower positive potential than said conductive means, means for causing at least a major portion of said primary beam to diverge and impinge upon said dynode around said aperture to produce a hollow cylindrical beam of secondary electrons displaced outwardly from said primary beam and directed through said conductive means in a direction opposite to said primary beam, an auxiliary electrode comprising a solid portion located on said axis and adjacent to said dynode, means for applying to said auxiliary electrode a potential between the potentials of said dynode and said conductive means, and means for substantially confining said beams to their respective paths.

2. Means according to claim 1, wherein said electron gun includes an electrode having an aperture of approximately the same diameter as said dynode aperture for collecting said beam of secondary electrons.

3. Means according to claim 1, further including means for varying the potential of said auxiliary electrode to vary the electric field pattern of said dynode.

4. Means according to claim 1, wherein said auxiliary electrode comprises a rod having a tapered end disposed coaxially within said aperture in said dynode.

5. Means according to claim 1, wherein said auxiliary electrode comprises a plate extending across said axis in a plane beyond said dynode.

6. Means for producing two oppositely-traveling radially-displaced hollow cylindrical electron beams of different velocity, comprising an elongated envelope having a longitudinal axis, an electron gun including an annular cathode in one end of said envelope for projecting a hollow cylindrical primary beam of given outer diameter along said axis, electrode means in the opposite end of said envelope for collecting said primary beam comprising a dynode having an aperture of larger diameter than said primary beam coaxial with said axis, hollow conductive means forming

5

a drift space between said electron gun and said dynode, means for establishing a focusing field along said axis, means for biasing said dynode at a lower positive potential than said conductive means, means for causing said primary beam to diverge and impinge upon said dynode 5 around said aperture to produce a hollow cylindrical beam of secondary electrons displaced outwardly from said primary beam and directed through said conductive means in a direction opposite to said primary beam, an auxiliary

6

electrode comprising a solid portion located on said axis and adjacent to said dynode, and means for applying to said auxiliary electrode a potential between the potentials of said dynode and said conductive means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,518,954	Steele	Aug. 15, 1950
2,581,408	Hamilton	Jan. 8, 1952