

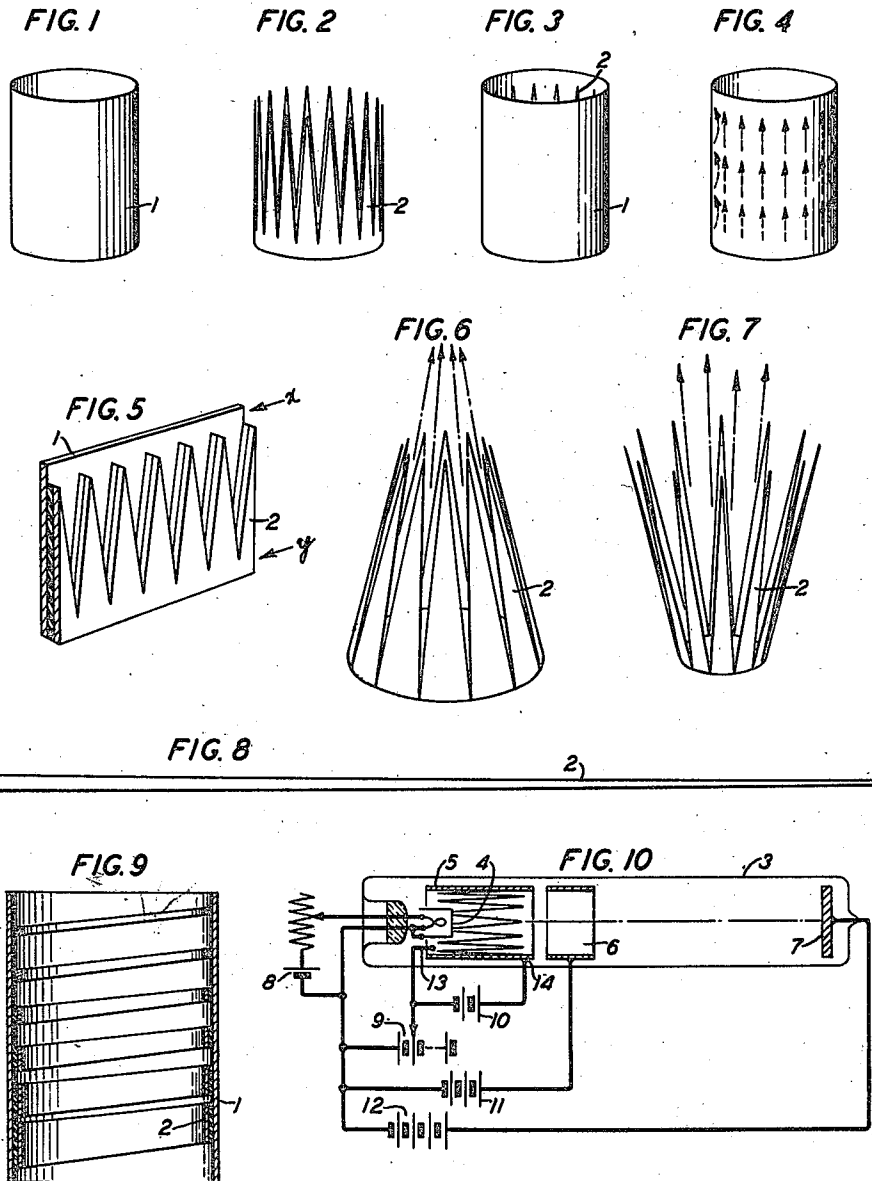
March 2, 1943.

F. B. LLEWELLYN
ELECTRON DISCHARGE DEVICE

2,312,723

Filed Aug. 16, 1939

3 Sheets-Sheet 1



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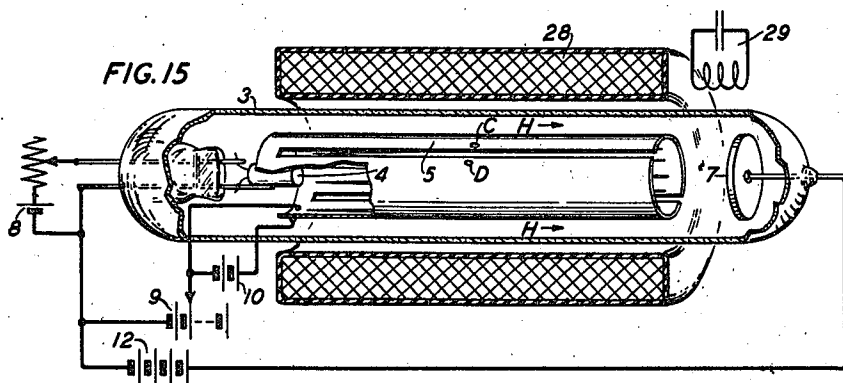
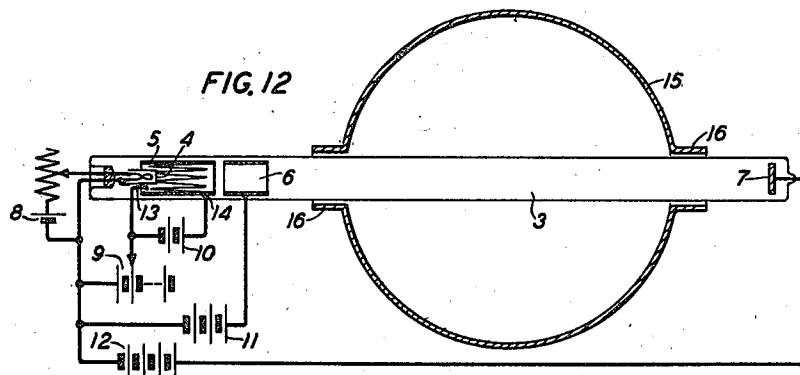
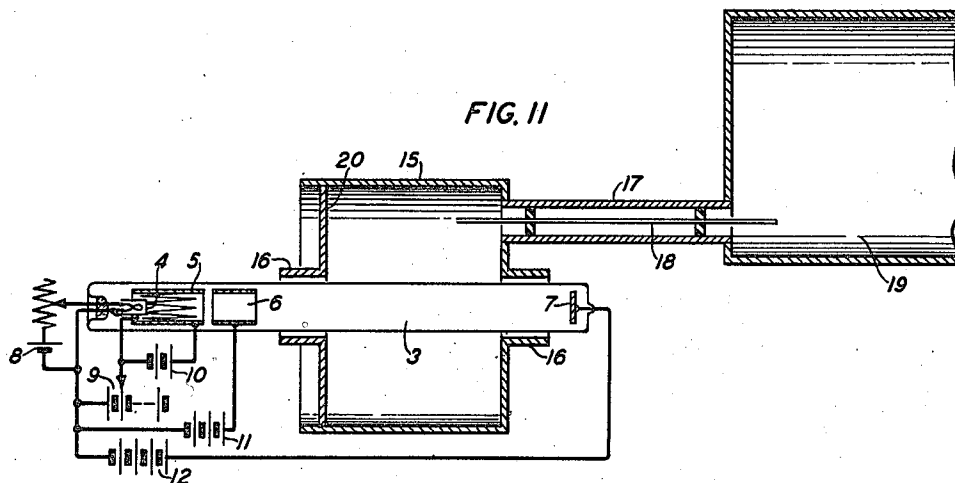
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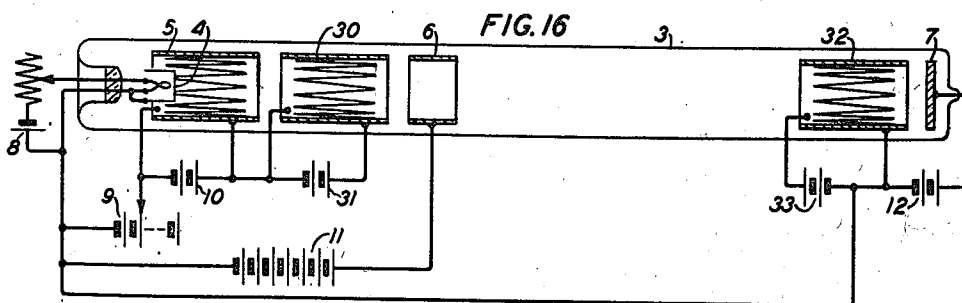
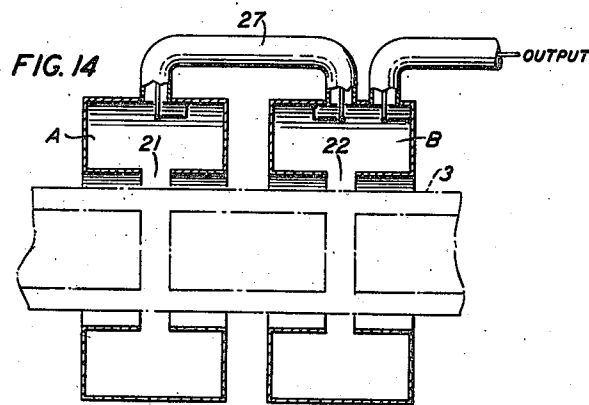
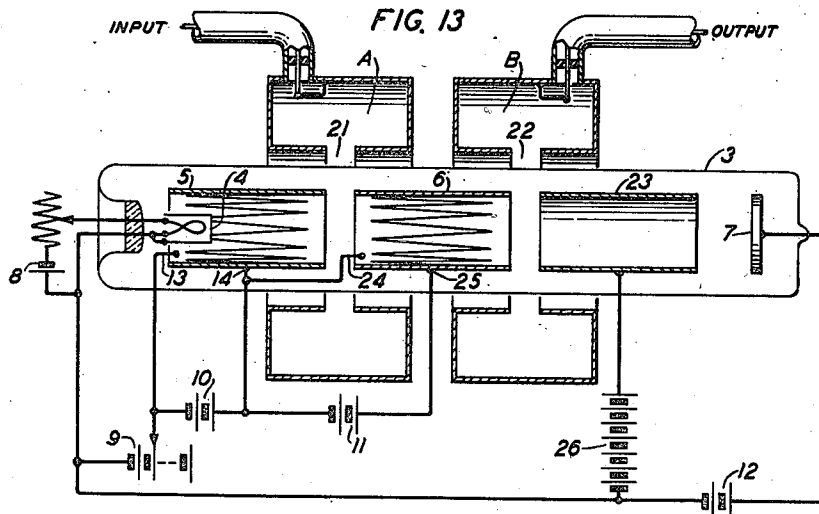
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ELECTRON DISCHARGE DEVICE

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,312,723

ELECTRON DISCHARGE DEVICE

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Application August 16, 1939, Serial No. 290,387

14 Claims. (Cl. 250—36)

The present invention relates to ultra-high frequency circuits employing electronic apparatus for amplification or oscillation production and more particularly to those types of such apparatus which utilize a stream of electrons as may be obtained from what is commonly termed an electron gun.

A principal object of the invention is to provide in ultra-high frequency generating and amplifying apparatus an electron stream of high current intensity to permit relatively high power operation.

Another object is to prevent dispersion of electrons along the path of the stream thereby avoiding losses due to some of them striking various elements of the apparatus.

Another object is to produce a convergent or divergent field for such propagation of an electron stream.

Another object is to provide means for controlling the field in the immediate vicinity of an electron emitting cathode located in the field of an accelerating electrode so that the electrons may be drawn from the emitter in either a parallel, convergent or divergent stream.

A further object is to provide in a split plate type of magnetron generator an electric field which will project electrons divergently in radial directions from a point cathode at one end of the plate, thus avoiding the necessity for a cathode between the plates which would be susceptible to bombardment, and then carry them axially toward a collector thus avoiding congestion of electrons in the space between the plates.

In many circuits utilizing electron discharge tubes there is need for projecting an electron stream of high current intensity over a relatively long path and difficulties are encountered both in initiating such a stream and in avoiding energy loss through the dispersion of electrons along its path. These difficulties are minimized according to this invention through the use of a longitudinal accelerating field produced by a form of electrode which surrounds the electron path and distributes the field producing potentials advantageously with respect to it. It is to be understood in this specification and the appended claims that the term "accelerating," or variations of it, when used without qualification may refer to either positive or negative acceleration and that the qualifications "positive" and "negative" are to indicate that the accelerating force is applied to the electrons in the direction away from the emitter and in the op-

posite direction respectively. The electrode may be connected to either positively accelerate, that is, increase the velocity of a stream of electrons away from the emitter or to negatively accelerate, that is, decrease the velocity away from the emitter or reverse the direction of a stream of electrons. A typical electrode achieving the desired result consists of two parts of conducting material insulated from each other and maintained at different potentials according to the intensity of the electric field desired. Each part may be either integral or made up of a multiplicity of elements properly insulated and interconnected, the essential feature being that the portions of each part effective in producing the field be disposed around the axis of the electron path and along the axis in such a manner that the effective amounts of material at the two different potentials preponderate at different ends of the electrode enclosing space and extend in decreasing amounts and interspersed with each other to the opposite ends. Since the electric field at any point is produced by the resultant effect of the adjacent portions of the two parts of the electrode which are at different potentials it will be seen that the field will vary along the axis of the electrode in accord with the relative amounts of the effective material at each potential. The potential of the field will be greatest at one end of the electrode, and least at the other end with intermediate values in between. When the parts of the electrode are placed symmetrically around the axis the planes at right angles to the axis will be equipotential at all points along the electrode. An electrode may be made up of more than two parts and energized with more than one potential difference or several electrodes may be placed in tandem to extend the length of the enclosed electron path or to obtain a field of higher potential difference.

An electric field of the type thus produced is particularly adapted to extracting electrons in a parallel beam from a cathode placed within it and to maintaining the beam parallel over an extended length of path. This property is of value in connection with the generation and control of ultra-high frequency power. It is of particular value in the application of electron guns to the generation of high frequency power such as where an electron stream is sent through a field associated with an electrically resonant chamber or circuit as referred to in my copending application Serial No. 156,647 filed July 31, 1937, patented February 20, 1940, Patent No.

2,190,668, or when what is sometimes referred to as velocity modulation is employed, where the electron stream is subjected to different field conditions in different parts of its path as shown in my prior Patent No. 2,096,460 issued October 19, 1937. This velocity modulation process is discussed quite extensively in an article by Messrs. W. C. Hahn and G. F. Metcalf in the Proceedings of the Institute of Radio Engineers, vol. 27, February 1939, pages 110 to 116, and is touched upon briefly in a note by R. H. Varian and S. F. Varian in the Journal of Applied Physics, vol. 10, February 1939, page 140.

Several possible variations of the electrode structure are shown including structures to produce convergent or divergent as well as parallel electron beams. Amplifier and oscillator circuits and an arrangement for excitation of a wave guide all adapted to use of the parallel electron beam are shown and also the application of a beam divergent at the cathode to a split plate magnetron employing in the plate the composite electrode structure.

The various features of the invention will be more fully understood from the following detailed description of the illustrative embodiments shown in the accompanying drawings.

In the drawings:

Figs. 1, 2 and 3 illustrate a method of fabricating a composite electrode, cylindrical in form, to produce the desired type of parallel accelerating field;

Fig. 4 indicates the nature of the electric field within the cylindrical electrode of Fig. 3;

Fig. 5 is a development of a section of the cylindrical electrode of Fig. 3 to indicate more clearly the relations of the elements;

Figs. 6 and 7 show variations in the element of Fig. 2 to produce either convergent or divergent fields;

Figs. 8 and 9 show an alternative to the method of construction shown in Figs. 1, 2, 3 and 5;

Fig. 10 shows an electron gun employing the composite electrode to produce the desired type of accelerating field and means for controlling the character of the electron stream as it leaves the cathode;

Fig. 11 shows the axial section of a resonant chamber such as a short section of cylindrical wave guide arranged for excitation by an electron gun of the type shown in Fig. 10 and connection to a wave guide for transmission of the high frequency energy;

Fig. 12 shows a transverse section of a cylindrical wave guide arranged for direct excitation by an electron gun of the type shown in Fig. 10;

Fig. 13 shows an ultra-high frequency amplifier circuit utilizing composite electrodes and resonant cavities as circuit elements;

Fig. 14 shows a modification of Fig. 13 to convert it to an oscillator circuit;

Fig. 15 shows an adaptation of the composite electrode structure to a type of split plate magnetron; and

Fig. 16 shows a tandem arrangement of composite electrodes in an electron gun and also a composite decelerating electrode.

In Figs. 1, 2 and 3 which show one method of constructing a composite electrode for producing a compact uniform accelerating field the two essential parts, 1 and 2, are indicated in Fig. 1 and Fig. 2. In Fig. 1 is represented a tube, 1, which is composed of conducting material and forms the outer element of the composite elec-

trode. In Fig. 2 is shown another tube, 2, of conducting material which has been cut in the form of a crown. In the assembly, the tube 2 is inserted inside of 1 but in such a way that electrical contact between the two conducting surfaces is avoided. One way of accomplishing this is to coat the outside of the crown 2 with an insulating material. For example, if 2 is made of aluminum, it may be processed to form aluminum oxide on the outer surface. Another method is to dip the crown into molten glass to provide a thin coating, taking care that the inner surface is clean of dielectric. Yet a third method is to employ vacuum dielectric, mounting the crown within the tube 1 in such a way that a thin insulating space is maintained. Whichever method is used, the assembly is shown in Fig. 3 where the points of the crown are just visible in the perspective drawing. In operation, the two tubes 1 and 2, respectively, are biased to different potentials. For example, suppose that 1 be placed at 100 volts and 2 at zero. The resulting field distribution is shown in Fig. 4. Its form may be derived from the following considerations. At the top of the assembly, Fig. 3, the potential is evidently the same as that of the outer tube 1, namely 100 volts. This is because the periphery of the assembled electrode at the top is composed entirely of material 1 at 100 volts. On the other hand the potential at the bottom of the assembly is evidently that of the inner crown 2 because the material forming 2 completely covers that of 1 at the lower edge of the assembly. The potential at that plane is thus the same as of 2, namely zero. This relation of the parts may be more evident from an inspection of Fig. 5 which is a development of a portion of the assembly Fig. 3 showing only material of cylinder 1 exposed inwardly at X, the top or 100 volt potential end of the electrode, and only material of the crown 2 exposed inwardly at Y, the bottom or zero potential end of the electrode. In Fig. 5 the thicknesses of the materials are exaggerated for clearness. Since at intermediate points along the axis portions of both materials are exposed inwardly, planes at intermediate points perpendicular to the axis will form equipotential surfaces intermediate between zero and 100 volts, and the lines of force are, therefore, distributed along the axis of the cylinder as shown in Fig. 4. Close to the periphery of the cylinder, the lines of force are distorted because of the striated form of the walls. But, provided these striations are small in size compared with the radius of the tube, the distorted field penetrates only a small way into the interior of the cylinder. As a matter of practical construction, the striations do not need to be much smaller than the distance between the periphery and the outer surface of the electron beam which it is intended shall pass through in order that the field acting on the electrons in the beam shall be substantially axial. An analysis indicating the uniformity of the field from such a composite electrode is given in a co-pending application of Frank Gray, Serial No. 290,359, filed August 16, 1939.

Modifications of the structure shown in Figs. 1, 2 and 3 to provide fields which will cause the electron beam to converge or diverge are indicated in Figs. 6 and 7 which show crown-shaped parts corresponding to 2 of Fig. 2, for electrodes to produce converging, or diverging beams respectively. The part 1, Fig. 1, would necessarily

be tapered also to fit the desired tapered part 2 shown in either Fig. 6 or Fig. 7.

An alternative form of constructing the composite electrode is shown in Figs. 8 and 9. Instead of the inner electrode being formed in the shape of a crown as shown in Fig. 2, a tapered strip of conducting material 2, Fig. 8, insulated on one side, is wound inside of an outer conducting cylinder 1, Fig. 9, similar to 1, Fig. 1, so that the assembly will appear as in Fig. 9, which is a section through the axis of revolution. It is seen that here also the relative amounts of the two materials exposed vary from end to end of the electrode which will vary the electric field along the axis accordingly. This construction has the advantage that the distorting striations near the walls of the tube are of such a nature that they tend to prevent any electrons which are moving near the wall from hitting it, and thus tend to decrease stray currents to the electrode. In constructing the electrode of Fig. 9, one method is to wind the tapered strip upon a mandrel and then cut the outer tube in two parts by a saw-cut through its axis. The two halves of the outer tube may then be placed over the tape on the mandrel, and fastened in place, after which the mandrel may be removed.

Fig. 10 shows an electron gun suitable for many uses including the applications indicated above utilizing a composite electrode for the purpose of extracting electrons from a cathode and projecting them in the form of a parallel beam along a path determined by the axis of the gun. In this figure an evacuated tube 3 contains a cathode 4 the emitting surface of which is disposed substantially perpendicular to the axis of the desired electron beam, composite positively accelerating electrode 5, auxiliary accelerating electrode 6 and collector plate 7. The composite electrode 5, which is indicated for illustration to be of the construction shown in Fig. 3, surrounds the cathode 4 which is the source of electrons. The cathode 4 is normally biased by means of battery 9, or equivalent, to a potential near that of the space adjacent to it as determined by the electrode 5, so that the electrons are extracted in a parallel beam. However, a focussing effect may be had by biasing the cathode to a potential slightly different from that of the surrounding space. For example, if the cathode potential is lower than that of the space the equipotential surfaces will be dish-shaped instead of flat in the vicinity of the cathode and the lines of force will cause the electrons to diverge leaving the cathode. Conversely, if the cathode potential is higher than that of the space the electrons will converge leaving the cathode. In order to control desirably the structure of the electron stream in this manner the source of biasing potential 9 is conveniently made adjustable. The cross-sectional area of the beam may be somewhat controlled since the biasing of the cathode curves the equipotential surfaces only in the immediate vicinity of the cathode and the beam becomes substantially parallel further on in the composite electrode after having converged or diverged over a short distance just after leaving the cathode. A cathode heating source is indicated by battery 8.

The composite electrode 5 is shown polarized by battery 10 which is connected to the two parts of the electrode so that the part preponderating more distant from the cathode, terminal 14, is the more positive in order to extract electrons from the cathode and project them toward the

collector 7. The terminal of the part preponderating nearer the cathode is indicated at 13 and is connected to the negative terminal of battery 10. Subsequent to the composite electrode 5 in the path of the beam a high potential accelerating electrode 6, energized by battery 11, is shown which may be employed if desired to further accelerate the electron stream. After the electron stream has delivered energy to a high frequency field the spent electrons may be collected at relatively low potential at collector 7 and returned to the cathode.

Fig. 11 shows the electron gun of Fig. 10 adapted to the excitation of a short section of wave guide and a method of transferring the high frequency energy generated therein for transmission through a wave guide. The electron gun 3 is inserted along the axis through the short section of wave guide 15 which constitutes the resonant cavity described in my Patent 2,190,668 and shown in Fig. 10 therein. The stream of electrons will react with the type of electric field within the section of guide which consists of symmetric longitudinal loops with the lines of electric force passing along the axis and along the enclosing conductor of the guide and this type of wave will be produced by the electrons when their transit time is equal to the period of $1\frac{1}{4}$, $2\frac{1}{4}$, $3\frac{1}{4}$, etc., cycles of the high frequency as explained in the above-mentioned copending application. The coaxial line consisting of the outer conductor 17 and the inner conductor 18 is shown arranged to transfer the high frequency energy in such a wave to the wave guide 19 by virtue of the inner conductor 18 projecting into both sections of guides in a manner to couple with the electric fields. The small projecting cylinders 16, 16 placed at the openings through which the electron gun is inserted are to prevent loss through radiation through those openings, the cylinders being made of sufficiently small diameter that the frequency of the energy within the guide is too low for them to transmit acting as wave guides.

Since the output and efficiency of a high frequency generator of this type depends so greatly upon the intensity and definition of the electron stream the use, as here shown, of the composite electrode 5 which is capable of extracting from the cathode and projecting a parallel electron beam of high energy content greatly facilitates the production and transmission of a relatively large amount of high frequency energy.

Another method of utilizing the electron gun of Fig. 10 to produce high frequency waves in a wave guide is shown in Fig. 12. Here the electron gun is shown passing transversely through the cylindrical wave guide 15. The small projecting cylinders 16, 16 are placed at the openings of the wave guide to prevent loss through radiation as explained in connection with Fig. 11. The components of the electron gun and the connections to it are the same as shown in Fig. 10 and here again the high voltage accelerating electrode 6 may be used or not as requirements indicate. It is apparent that the stream of electrons passing transversely through the cylindrical guide is capable of reacting with a type of electric field within the guide which consists of asymmetric loops with the lines of electric force passing transverse to the axis and around the two halves of the enclosing conductor in opposite directions and this type of wave will be produced by the electrons when their transit time is as indicated above in connection with Fig. 11.

The arrangement of Fig. 12 is quite similar to that of Fig. 14 of my copending application Serial No. 156,647 referred to above in that the portion of the wave guide immediately surrounding the electron gun must be closed off to the proper length with a plunger and an iris diaphragm to determine the frequency and extent of radiation as indicated in that application and shown in the associated Fig. 14.

Another application of the composite electrode to the problem of projecting a high energy electron beam is shown in Figs. 13 and 14 representing a high frequency amplifier and oscillator circuit utilizing the principle of velocity modulation, which, as previously mentioned, is described in considerable detail by Messrs. Hahn and Metcalf in the Proceedings of the Institute of Radio Engineers, vol. 27, February 1939, pages 110 to 116 and is also referred to in an application of it described by Messrs. R. H. Varian and S. F. Varian in the Journal of Applied Physics, vol. 10, February 1939, page 140. In Fig. 13, A is a resonant cavity of the circular reentrant type which serves as the input circuit and may be coupled to an input line as shown. B is a similar resonant cavity serving in a similar manner as the output circuit. The cathode heated by battery 8 is located within the composite electrode 5 which is energized by battery 10. The electrode 5 and cathode 4 are operated in the manner described in connection with Fig. 10 to project a stream of electrons through the fields of A and B at 21 and 22, respectively, and the cathode is biased by means of battery 9 to obtain the proper shape of emission as described in connection with Fig. 10. A second composite electrode 6, energized by battery 11 and a third electrode 23, energized by battery 26, which may or may not be of the composite type direct the electrons through to the electrode 7, energized by battery 12, where they are collected. Terminal 25 of 6, and terminal 14 of 5, are the connections to the parts of the respective electrodes which preponderate farther from the cathode and are made positive relative to terminals 24 of 6 and 13 of 5, respectively, which are the connections to the parts of the respective electrodes which preponderate nearer to the cathode. The arrangement shown in Fig. 13, is that of an amplifier with input and output connections as indicated. The electron stream from the cathode 4 to the collector 7 passes through the electric field of cavity A for a short distance at 21 and through the field of cavity B for a short distance at 22. The alternating field at 21 due to the current in A which is derived from the input to the amplifier reacts upon the electron stream to speed up those electrons which enter the field during one half of each cycle and to retard those which enter during the other half cycles. After leaving the region of the field at 21 the electrons which have had their velocity increased tend to overtake those which have had their velocity reduced so that by the time the region of the field at 22 is reached a rearrangement of the electrons along the stream has taken place and the stream is no longer of uniform density. Regions of greater and less electron density alternate in accordance with the effect of the field at 21. In other words, the electron stream has been density modulated in accordance with the input to the amplifier. Now in passing through the region 22 of cavity B the variations in the density of the electron stream will induce a varying current in B proportional to the input to A and, of course, of the same frequency, so

that the input high frequency energy is amplified and delivered through the output line coupled to B. The alternating field produced at 22 by the current in B will oppose the passage of the electrons and reduce their velocities, the spent electrons are removed from the vicinity of region 22 by the electrode 23 and collected at relatively low potential by the collector 7. As with any amplifier, this circuit may be readily modified to act as an oscillator by coupling a portion of the output energy to the input. A method of doing this is shown in Fig. 14. A coaxial line 27 couples the two cavities A and B in order to excite the input circuit A with energy from B. The line 27 must be of such length and the electron transit time between points 21 and 22 such that the currents in A and B are in proper phase relation to cooperate in sustaining oscillations.

Another application of the composite electrode structure is illustrated in Fig. 15 which shows the active elements of a split plate magnetron in which the split plate 5 is of composite construction. The form of construction shown is that of Fig. 3 though alternative forms will serve equally well. An axial magnetic field indicated by H secured by means of coil 28 is employed. The source of electrons is the cathode 4 which in this case is biased below the potential of its surrounding space so that the electrons are drawn off sharply diverging in radial directions as explained in connection with the description of Fig. 10 where reference is made to the focusing effect of biasing the cathode to a potential different from that of the surrounding space. The electrons spiral at approximately right angles to the axis between the axis and the plate and deliver energy to the alternating field existing between the split in the plate thus delivering energy to the circuit including the plate and to the output circuit 29. The output circuit which is indicated at 29 may be of any desired form which will couple with the alternating field of the magnetron when placed in proximity to it. As an alternative, direct connection may be made to the plate of the magnetron at appropriate points such as C and D, the position along the plate, assuming the magnetron elements are not part of an external tuned circuit, being determined by the impedance of the load circuit to be attached. The longitudinal electric field of the composite plate 5 moves the spiraling electrons axially toward electrode 7 where they may be collected at relatively low potential. For very high frequency operation it is convenient to make the split plate $\frac{1}{4}$ wave-length long the parts being connected together at the cathode end as shown in Fig. 15. For lower frequency use it is desirable to have no internal high frequency connection between the parts of the plate and to make them part of an external tuned circuit. The connection of battery 10 is such that the positive terminal is connected to the external portion of the plate, corresponding to 1 of Figs. 1 and 3, and the negative terminal is connected to the inner crown-shaped member, corresponding to 2 of Figs. 2 and 3, which must be insulated from the external portion for the direct voltage of 10 and must be split longitudinally the same as the outer portion as shown in Fig. 15. The most positive end of the field of the composite structure due to the potential of battery 10 is in the direction toward collector 7 from the cathode 4. The battery 9 is for the purpose of biasing the cathode 4 below the surrounding space potential in order to obtain the radially divergent

stream of electrons from the cathode. It will be seen that this structure is free from any obstruction, such as a cathode, within the split-plate cylinder and along its axis which may be bombarded by moving electrons entailing energy loss and damage and also that the longitudinal field due to the composite electrode structure of the split plate will effectively clear the space between the plates of spent electrons.

Fig. 16 is similar to Fig. 10 and shows some alternative arrangements of composite electrodes in the electron gun of Fig. 10. An additional composite positively accelerating electrode 30 which is energized by source 31 is shown in tandem with electrode 5. As mentioned previously a number of composite electrodes may be placed in tandem to obtain higher potential accelerating fields. The auxiliary electrode 6 may or may not be used as the requirements of the application indicate. Electrode 32 is shown to illustrate the use of a composite negatively accelerating electrode. It is constructed the same as a positively accelerating electrode such as 5, but is connected to its source of potential 33 so that its more positive end is directed toward the emitter and away from the collector 7 to that its field will tend to retard the electrons before they strike the collector thereby minimizing the energy to be dissipated in the form of heat at the collector. In general, in the various applications of the electron gun illustrated, where the gun of Fig. 10 is shown or referred to the gun of Fig. 16 or some other similar modification of the Fig. 10 arrangement may be substituted. Any of the composite electrode structures shown may be connected with respect to polarity to give either positive or negative acceleration to the electron stream and to any of the utilization circuits shown one or more negatively accelerating electrodes may be added to retard or reverse the electron stream.

With the examples that have been given of forms of embodiment, various modifications for use of the composite electrode in electron gun applications will naturally suggest themselves to those skilled in the art and it is intended that the invention is not to be limited to the specific forms disclosed but only by the scope of the claims.

What is claimed is:

1. In combination, a space discharge tube comprising an electron emitter, a positively accelerating electrode surrounding the path of electron discharge for at least a portion of its length and also the electron emitter in directions perpendicular to the path, the said accelerating electrode being of composite construction composed of two conducting elements insulated from each other and with those portions of the surfaces of the elements which are directly exposed to the path commingled so that the combined surface which is exposed to the electron stream, and thus capable of affecting it, varies along the direction of the path from being substantially entirely of one element at one place to being substantially entirely of the other element at another while in between the combined exposed surface is a mixture of the two elements the portion of each diminishing in the direction of where the other preponderates, and an electron collector at the end of the discharge path, means for maintaining the elements of the composite positively accelerating electrode at different potentials such that the element which preponderates farthest from the electron emitter is more positive, means

for maintaining the electron collector at a positive potential with respect to the emitter and a resonant cavity surrounding at least a portion of the tube and through which the electron path extends wherein by virtue of the critical relation between the operating frequency and the transit time of the electrons through the cavity energy is transferred from the electron stream to the cavity.

2. In an oscillation generating circuit an electron discharge tube comprising an electron emitting cathode, a plurality of plates surrounding and extending along an axis including the cathode, the cathode being located between and near one end of the plates, the plates being insulated from each other throughout portions of their length, each plate being composed of two conducting elements insulated from each other and with those portions of the surfaces of the elements which are exposed directly to the aforementioned axis commingled so that the combined surface of each plate exposed to the axis varies along the direction of the axis from being substantially entirely of one element at one end of the plate to being substantially entirely of the other element at the other end while in between the combined exposed surface is a mixture of the two elements, the portion of each diminishing in the direction of the end where the other preponderates, means for maintaining the two elements of each plate at different potentials such that the element which preponderates farthest from the cathode is more positive, means for maintaining the cathode at a potential lower than that of the space in the transverse plane including the cathode which is produced by the potentials of the plates, means for maintaining a magnetic field parallel to the axis and in the direction of the plates away from the cathode, an electron collector at the end of the plates opposite the cathode, means for maintaining the collector positive with respect to the cathode and an output circuit coupled to the plates.

3. In an electron discharge device, an accelerating electrode surrounding at least a portion of the discharge path utilizing two concentric elements of conducting material, one fitting inside of the other and insulated from each other so that a difference of potential may be maintained between them, the internal element being so formed that the amount by which it covers or shields from within the interior surface of the outer element varies from one end of the electrode to the other.

4. In combination, a source of electrons, a tubular conducting member surrounding the path of electron discharge for at least a portion of its length and another member insulated from the first member and positioned within it to overlap portions of its inner surface as viewed from the electron stream, means for impressing an electromotive force between the two members, the inner member having openings to expose the electron stream to the field of the outer member, the areas of the openings increasing progressively with distance from one end of the assembly to the other so that the resultant electric field in which the electrons are moving is substantially uniform.

5. In an electron discharge device an accelerating electrode surrounding at least a portion of the discharge path utilizing two concentric elements of conducting material, one fitting inside of the other and insulated from each other so that a difference of potential may be maintained between them, the external element having a

complete tubular surface, the inner element being deeply serrated on one end as if made up of tapered or triangular elements with the bases contiguous at one end and the points or apexes separated at the other end so that the outer element is completely covered or shielded at the end where the bases are positioned and completely uncovered or unshielded at the end where the points or apexes are positioned.

6. In combination, an electron emitter and an accelerating electrode consisting of at least two series of commingled but non-overlapping areas of conducting members surrounding the electron emitter and the path of discharge of emitted electrons in directions perpendicular to the said path, the series being insulated from each other and subjected to different potentials to produce a joint substantially uniform electric field in which the electrons are accelerated, and means to impress a potential upon the electron emitter positive with respect to that of the virtual potential of the accelerating electrode in the plane including the emitter so as to tend to focus the electron discharge beam.

7. The combination according to claim 6 in which the voltage impressed upon the electron emitter is negative with respect to that of the virtual potential of the accelerating electrode in the plane including the emitter so as to tend to diverge the electron discharge beam.

8. The combination according to claim 6 in which the voltage impressed upon the electron emitter is the same or slightly different from the virtual potential of the accelerating electrode in the plane including the emitter so as to tend to maintain the parallelism of the electron discharge beam.

9. An electric wave transmission apparatus comprising an electron discharge device having a source of electrons, an anode and a control element interposed between the electron source and the anode and surrounding the path of electron discharge for at least a portion of its length and also the electron source in directions perpendicular to the path, the control element comprising two conducting members insulated from each other and having such conformation that the surface exposure to the electron stream of one member increases along the electron stream as the surface exposure of the other member to the stream decreases, means for polarizing the two members of the control element at different potentials with respect to the electron source whereby the stream of electrons emanating from the electron source is accelerated uniformly within a given zone to produce a high intensity electron stream, means for polarizing the anode positively with respect to the cathode, the conducting members of the control element being divided longitudinally throughout most of their length except for a connection at one end to constitute an electrically resonant circuit comprising conducting surfaces symmetrically positioned with respect to the electron stream to set up an electromagnetic field through which the electron stream passes whereby upon reaction between the electromagnetic field and the high intensity electron stream a large energy transfer occurs from the stream to the electromagnetic field and means for withdrawing wave energy from the electromagnetic field.

10. A space discharge device comprising an electron emitting cathode, an anode, means for polarizing the anode positively with respect to the cathode, a control electrode interposed between

the cathode and anode and surrounding the path of electron discharge for at least a portion of its length including its point of origin at the cathode, the control electrode serving to accelerate electrons uniformly within a given zone and comprising two conducting members insulated from each other and having such conformation that the surface exposure of one member increases along the electron stream as the surface exposure of the other member to the stream decreases and means for polarizing the two members at different potentials with respect to each other and to the cathode, means for producing high frequency variations in the electron stream, an output circuit and means responsive to high frequency variations in the electron stream for transferring energy therefrom to the output circuit.

11. An electric wave transmission apparatus comprising an electron discharge device having a source of electrons, an anode and a control element interposed between the electron source and the anode and surrounding the path of electron discharge for at least a portion of its length including its place of origin at the electron source, the control element comprising two conducting members insulated from each other and having such conformation that the surface exposure to the electron stream of one member increases along the electron stream as the surface exposure of the other member to the stream decreases, means for polarizing the two members of the control element at different potentials with respect to the electron source whereby the stream of electrons emanating from the electron source is accelerated uniformly within a given zone to produce a high intensity electron stream, means for polarizing the anode positively with respect to the cathode, means for setting up an alternating electromagnetic field in a zone through which the electron stream passes whereby upon reaction between the electromagnetic field and the high intensity electron stream a large energy transfer occurs from the stream to the electromagnetic field and means for withdrawing wave energy from the electromagnetic field.

12. In combination, a space discharge tube comprising an electron emitter, a positively accelerating electrode surrounding the path of electron discharge for at least a portion of its length and also the electron emitter in directions perpendicular to the said path and being of composite construction composed of two conducting elements insulated from each other and with those portions of the surfaces of the elements which are directly exposed to the path commingled so that the combined surface which is exposed to the electron stream, and thus capable of affecting it, varies along the direction of the path from being substantially entirely of one element at one place to being substantially entirely of the other element at another while in between the combined exposed surface is a mixture of the two elements the portion of each diminishing in the direction of where the other preponderates, and an electron collector at the end of the discharge path, means for maintaining the elements of the composite positively accelerating electrode at different potentials such that the element which preponderates farthest from the electron emitter is more positive, means for maintaining the electron collector at a positive potential with respect to the emitter and a resonant cavity surrounding at least a portion of the tube and through which the electron path extends wherein

by virtue of the critical relation between the operating frequency and the transit time of the electrons through the cavity energy is transferred from the electron stream to the cavity.

13. An amplifier circuit comprising an electron discharge tube having an electron emitting cathode, a positively accelerating electrode surrounding a portion of the electron discharge path and also the emitting portion of the cathode in directions perpendicular to the said path, the said accelerating electron being of composite construction, composed of two conducting elements insulated from each other and with those portions of the surfaces of the elements which are directly exposed to the path commingled so that the combined surface which is exposed to the electron stream, and thus capable of affecting it, varies along the direction of the path from being substantially entirely of one element at one place to being substantially entirely of the other element at another while in between the combined exposed surface is a mixture of the two elements the portion of each diminishing in the direction of where the other preponderates and a collecting electrode at the end of the electron path, means for maintaining the elements of the composite positively accelerating electrode at different potentials such

that the element which preponderates farthest from the electron emitter is more positive, means for maintaining the collector at a positive potential with respect to the cathode, a cavity resonator positioned around the tube such that the electron stream passes through its field, an input coupled to said resonator for the electrical excitation thereof, a second resonant cavity positioned around the tube further along on the electron path such that the electron stream passes through its field for the purpose of delivering energy to it and an output circuit coupled to the second resonator.

14. In an electron discharge device, an accelerating electrode surrounding the electron emitter and at least a portion of the discharge path in directions perpendicular to the said path utilizing two concentric elements of conducting material, one fitting inside of the other and insulated from each other so that a difference of potential may be maintained between them, the internal element being so formed that the amount by which it covers or shields from within the interior surface of the outer element varies from one end of the electrode to the other.

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