

July 2, 1946.

W. C. BROWN

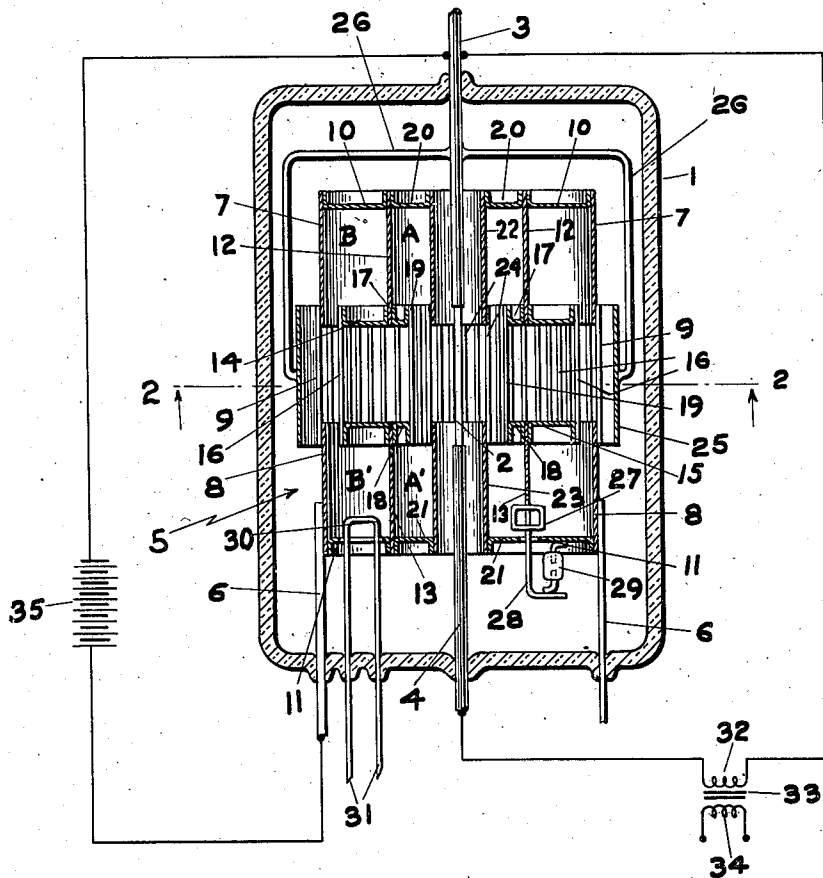
2,402,983

ELECTRONIC DISCHARGE TUBE

Filed Nov. 26, 1941

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FIG. 1.



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FIG. 2.

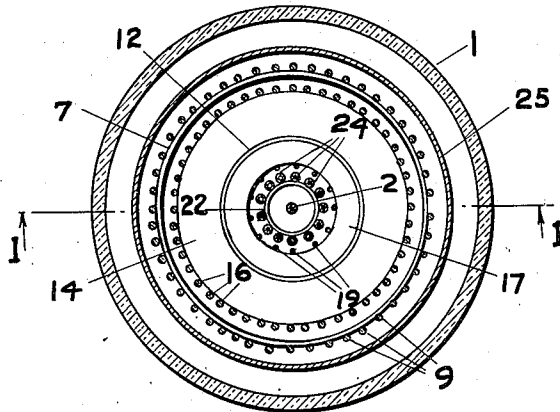


FIG. 5.

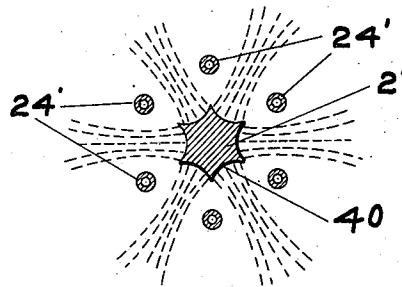
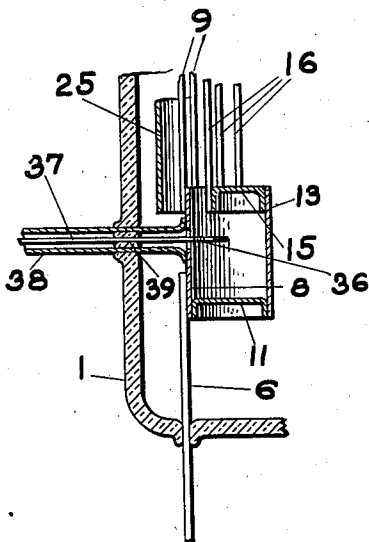


FIG. 4.



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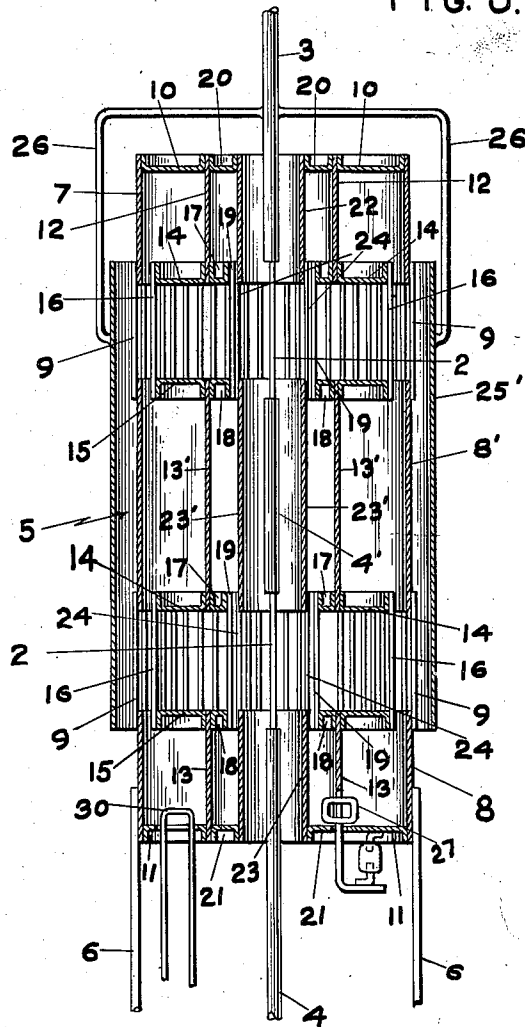
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FIG. 3.



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ELECTRONIC DISCHARGE TUBE

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5 Claims. (Cl. 250—27.5)

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This invention relates to electronic discharge tubes of the type in which ultra-high frequency currents are generated or amplified by means of electron velocity modulation or variation. Tubes of this kind have been made in which a pencil-shaped beam of electrons was produced and in which the velocities of the electrons were altered so as to produce localized concentrations or bunching of the electrons in the beam. Such tubes have had a number of drawbacks. The electrons in each dense grouping have had a tendency to repel each other and to cause "debunching" as the beam travelled along the tube. Also the amount of power available has been limited due to the limitation of the amount of current which can be carried through such a beam, and also because of other factors inherent in the foregoing type of tube. It has also been difficult to build pencil beam-producing cathode structures which were efficient, durable, and capable of supplying sufficient current for large power tubes.

An object of this invention is to produce an electron velocity modulating tube in which the debunching tendency is substantially decreased.

Another object is to increase the utilization of the electron emission and otherwise to increase the cathode effectiveness and efficiency in such a tube.

Another object is to produce a structure which can be made to dissipate power losses more readily.

A further object is to produce a compact and simple tube structure.

A still further object is to produce a tube of the foregoing type having cylindrical symmetry in which the electron beam is in the shape of a disk travelling radially from a central cathode.

The foregoing and other objects of this invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings wherein:

Fig. 1 is a longitudinal cross-section of an electron velocity modulation tube taken along line 1—1 of Fig. 2, and showing diagrammatically a circuit in which the tube may be utilized;

Fig. 2 is a transverse cross-section taken along line 2—2 of Fig. 1;

Fig. 3 is a longitudinal section similar to Fig. 1 of an electrode assembly of a multiple section tube;

Fig. 4 is a fragmentary section of an alternative means of coupling the output to a tube structure, such as shown in Fig. 1; and

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Fig. 5 is an enlarged cross-sectional view through an alternative form of cathode.

As shown in Fig. 1, 1 represents an envelope of some suitable material, such as glass. Contained within the envelope 1 is a cathode 2. This cathode may be made of a filament of the tungsten or thoriated type. This type of cathode can be operated at high temperatures to supply large values of thermionic emission. Also it can withstand other severe conditions, such as bombardment by ions, and still have a long and effective life. Under similar conditions, the ordinary oxide type of cathode might soon have its coating driven therefrom. Of course it is to be understood that oxide-coated cathodes or other types of cathodes may likewise be used in tubes of this kind under suitable conditions. The cathode 2 is supported between a pair of cathode lead-in conductors 3 and 4 sealed through the wall of the envelope 1.

Surrounding the cathode 2 and having cylindrical symmetry with respect thereto is an electrode structure 5. This electrode structure is constructed so as to impart velocity modulation or variation to the electrons passing therethrough. The electrode assembly 5 is supported by a pair of standards 6 which are sealed through the wall of the envelope 1 and constitute lead-in conductors. The outermost portion of the electrode assembly 5 consists of upper and lower metal cylinders 7 and 8 which are spaced apart so as to leave a cylindrical opening across which is interposed a plurality of vertical metal rods 9 supported by the lower and upper ends respectively of the cylinders 7 and 8. The vertical rods 9 form a grid structure through which electrons may readily pass. A pair of upper and lower annular disks 10 and 11 is secured in the upper and lower ends respectively of the cylinders 7 and 8. The inner edges of the disks 10 and 11 respectively support upper and lower cylinders 12 and 13, which thus are likewise spaced apart so as to provide a cylindrical opening similar to that existing between the cylinders 7 and 8. The spaced ends of the cylinders 12 and 13 respectively support annular disks 14 and 15. The outer edges of the disks 14 and 15 have secured thereto a plurality of vertical conducting rods 16 which form a grid similar to that formed by the vertical rods 9 and concentric therewith. The rods 16 are preferably in line with the rods 9 so that an electron beam may pass freely between each pair of rods 16 and likewise between each pair of rods 9 without encountering an interfering grid structure.

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The adjacent ends of the cylinders 12 and 13 likewise support annular rings 17 and 18 respectively. The inner edges of these rings have secured thereto a plurality of vertical conducting rods 19 likewise forming a grid structure concentric with the grid structures previously described. Here likewise the rods 19 are preferably in line with the rods 16 and 9, respectively.

A pair of annular disks 20 and 21 is likewise supported by the upper and lower ends respectively of the cylinders 12 and 13. The inner edges of the disks 20 and 21 support respectively a pair of cylinders 22 and 23, the adjacent ends of which are likewise spaced apart to provide a cylindrical opening. The adjacent edges of the cylinders 22 and 23 also support vertical conducting rods 24 across this cylindrical opening. The rods 24 form another grid similar to those discussed above. In this case likewise the rods 24 are preferably in line with the rods 19, 16 and 9, respectively.

Surrounding the grid 9 is a metal cylinder 25 constituting a collector electrode or anode. This cylindrical electrode is supported by a pair of conductors 26 electrically and mechanically connected to one of the lead-in conductors 3. In this way the collector anode 25 is maintained at substantially the same potential as the cathode 2.

In the arrangement as described above the structure provides upper and lower chambers A—A'. These chambers constitute oscillating circuits which when properly energized are caused to generate oscillations, the frequency of which is determined primarily by the dimensions of the chambers A—A'. Likewise upper and lower chambers B—B' are provided constituting oscillating circuits. The geometry of the chamber B—B' and the geometry of the chamber A—A' are preferably so related that the natural frequencies at which they oscillate are substantially equal. The chambers A—A' exist between the concentric cylinders 22 and 12 and between 23 and 13. The oscillating chambers B—B' exist between the concentric cylinders 12 and 7 and between 13 and 8. The chambers A—A' produce bunching of the electrons passing through the grids 24 and 19, while the chambers B—B' absorb energy from the bunched electrons passing between the grids 16 and 9. It is desirable to couple the chambers B and B' to the chambers A and A' so as to feed energy from the chambers B—B' to the chambers A—A', and thus produce sustained oscillations. For this purpose a coupling loop 27 is provided. This loop extends on opposite sides of an opening in the cylinder 13, and thus projects into both the chambers A' and B'. The loop 27 is supported on a wire 28 which in turn is insulatingly supported by a glass bead 29 from the lower wall of the electrode assembly 5.

In order to feed oscillations generated within the tube to some suitable external circuit, a coupling loop 30 extends through an opening in the annular disk 11 into the chamber B'. The two sides of this loop constitute lead-in wires 31 which are sealed through a wall of the envelope 1, and thus constitute means from which oscillating power generated within the tube may be utilized.

In order to provide the filament 2 with heating power, a secondary winding 32 of a heating transformer 33 is connected between the cathode lead-in conductors 3 and 4. The transformer 33 may be provided with a primary winding 34 connected to a suitable source of alternating current. A suitable unidirectional source of potential 35 is

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connected between the cathode 2 and the electrode structure 5. This potential may be of the order of 1000 volts, and has a polarity which makes the electrode structure 5 positive with respect to the cathode 2.

In the system illustrated in Fig. 1, the cathode 2 is raised to a temperature at which it emits electrons copiously. These electrons are accelerated under the action of the positive potential applied to the electrode structure 5, and pass through the grid 24 at relatively high speeds. The thermal agitation of the electron atmosphere which is thus created between the grids 24 and 19 sets up variations in voltage within the chamber A—A' which causes oscillations to be initiated therein. These oscillations impart voltage differences between the grids 24 and 19 which accelerate some of the electrons and decelerate others, causing the electron beam passing between the grids to become more dense at definite localized intervals along the electron beam as said beam travels along between the grids 19 and 16. This causes the electrons to enter the grid 16 in pulses or bunches.

The radial travel of the electron beam from the cathode greatly facilitates the bunching effect. As the electrons travel out from the cathode, normally the density of the electron stream would tend to decrease because of the increased transverse section of the electron stream. Thus it is possible to produce the bunching effect without actually increasing the density of the electron stream from what it is in the vicinity of the cathode itself. As a matter of fact, even before and after the bunching has taken place, an actual decrease in the electron density of the beam may take place without in any way decreasing the bunching effect. Thus the mutual repulsion which occurs between electrons can cause the electrons to spread out in the expanding cylindrical surface of each bunch of electrons without decreasing the total number of electrons in each bunch. This sharply distinguishes from the condition which exists in the pencil beam type of velocity modulated electron tube, in which the mutual repulsion of the electrons produces a decided tendency for de-bunching to occur.

As the electron groups or bunches pass through the grid 16 to the grid 9, they impart energy to that portion of the system represented by the chambers B—B'. In this way these chambers are forced to oscillate, and absorb energy from the electron stream.

Some of this energy is fed back through the coupling coil 29 to the chambers A—A', reinforcing the initial operation, and thus causing the system to generate sustained ultra-high frequency oscillations. The frequency of these oscillations depends largely on the geometry of the electrode system 5.

As the electrons issue from the grid 9, they are decelerated by the anode 25, due to the fact that it is substantially at cathode potential, and many of the electrons fall upon the anode 25 with relatively low velocities. Some of the electrons are reflected from the electrode 25, and fall back upon the electrode structure 5. This may be, for example, upon the outer surfaces of the cylinders 7 and 8. In this way the electrode structure 5 likewise constitutes a collector of the electrons.

In the above arrangement substantially the entire electron emission from the cathode 2 is effectively utilized in producing the active electron beam, and thus the efficiency of the cathode is

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increased over an arrangement in which only a part of the electron emission is thus utilized. It is also possible to make the vertical grid rods in hollow form, and to pass cooling water there-through so as to dissipate energy liberated at the grids. Thus, for example, in Fig. 2 the vertical rods 24 are illustrated as being hollow through which such cooling water may be circulated. The limitation of the amount of heat which can thus be dissipated has heretofore constituted one of the limitations in size of devices of this kind.

The electrode structure illustrated in Fig. 1 lends itself to a multiple section arrangement in which each electrode section reinforces the oscillations produced in each other section, thus enabling a multiplication of the power which the tube can generate. Such a multiple electrode assembly is illustrated in Fig. 3, in which the same reference numerals are applied where the elements are identical with those shown in Fig. 1. The multiple electrode assembly of Fig. 3 in effect is essentially two of the electrode assemblies of Fig. 1 placed end to end, and in which the adjacent transverse walls are eliminated. Thus in Fig. 3 the corresponding adjacent cylindrical elements of Fig. 1 are replaced by the cylindrical elements 8', 13', and 23'. The lead connecting the adjacent ends of the filaments 2 is designated by the numeral 4'. Also in Fig. 3 a common collector electrode 25' may be utilized surrounding both of the grids 9 and thus serving as a common collector for the two electron beams issuing from the multiple electrode structure. Of course, instead of utilizing a two-section electrode assembly as illustrated in Fig. 3, an additional number of such electrode assemblies may be consolidated into a single tube structure.

Instead of having the cathode in the form of a round filament, it can be shaped so as to focus the electrons emitted therefrom into localized beams so as to cause said beams to pass between the rods of the first grid, and thus prevent an excessive flow of current to said first grid. Such an alternative form of cathode is shown in Fig. 5. In this figure the cathode 2' has its surface configured to provide a series of circular grooves 40. The electrons, being emitted substantially normal to the surface of the cathode, are concentrated into localized beams which pass between each two adjacent grid rods 24', said grid rods being substantially similar to the grid rods 24 already described.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will suggest themselves to those skilled in the art. For example, instead of utilizing a coupling loop 30 in order to take off the oscillator power, a coupling system such as that shown in Fig. 4 may be utilized. In this arrangement a loop 36 extends through an opening in the cylinder 8, and has one end thereof connected to the inner side wall of said cylinder 8. The loop 36 is provided with a lead extension 37 which is surrounded by a conducting pipe 38, the inner end of which is fastened to the outer wall of the cylinder 8 around the opening through which the loop 36 projects. The pipe 38 is sealed through the wall of the envelope 1, and the seal 39 is likewise provided within the pipe 38 through which the conductor 37 passes. The pipe 38 and the conductor 37 constitute a concentric transmission line through which the high frequency power may be more effectively led from the tube system.

Tubes of the kind which I have described above

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can also be made to function as amplifiers as well as oscillators. They may also be used in circuits for detecting ultra-high frequency oscillations. It will be seen, therefore, that the parts of my invention as described above are capable of a wide variety of embodiments, and many equivalents other than those specified above will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A multiple section electron velocity modulation discharge device comprising a plurality of sections, each of said sections comprising a cathode, a cavity resonator adjacent thereto and adapted to have the electron stream emitted from said cathode pass through it, a pair of grids forming part of said cavity resonator and constituting the entrance and exit points with respect to said cavity resonator, and an additional electrode beyond said grids and adapted to intercept said electron stream as it emerges from said cavity resonator, all of said cathodes being electrically connected together, and said cavity resonators being electrically interconnected where loops of oscillations occur on said cavity resonators.

2. A multiple section electron velocity modulation discharge device comprising a plurality of sections, each of said sections comprising a central cathode, a cavity resonator adjacent thereto and adapted to have the electron stream emitted from said cathode pass through it, a pair of grids forming part of said cavity resonator and constituting the entrance and exit points with respect to said cavity resonator, and an additional electrode beyond said grids and adapted to intercept said electron stream as it emerges from said cavity resonator, said grids being concentric with their respective cathode and having substantial cylindrical symmetry with respect to said cathode, all of said cathodes being electrically connected together, and said cavity resonators being electrically interconnected where loops of oscillations occur on said cavity resonators.

3. A multiple section electron velocity modulation discharge device comprising a plurality of sections, each of said sections comprising a central cathode, a cavity resonator comprising a pair of conducting cylinders concentric with said cathode, said cylinders being electrically connected together at one end and each carrying a grid at the other end, each of said grids being interposed in the path of the electron stream emitted from said cathode and being substantial concentric with said cathode, and an additional electrode, all of said cathodes being electrically connected together, the grids of each of said sections being connected to the corresponding grid of the other of said sections by conducting cylinders.

4. A multiple section electron velocity modulation discharge device comprising a plurality of sections, each of said sections comprising a cathode, a cavity resonator adjacent thereto and adapted to have the electron stream emitted from said cathode pass through it, a pair of grids forming part of said cavity resonator and constituting the entrance and exit points with respect to said cavity resonator, and an additional electrode beyond said grids and adapted to intercept said electron stream as it emerges from said cavity resonator, all of said cathodes being electrically connected together, and said cavity resonators being electrically interconnected to cause

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oscillations generated in each of said sections to reinforce each other.

5. A multiple section electron velocity modulation discharge device comprising a plurality of sections, each of said sections comprising a central cathode, a cavity resonator adjacent thereto and adapted to have the electron stream emitted from said cathode pass through it, a pair of grids forming part of said cavity resonator and constituting the entrance and exit points with respect to said cavity resonator, and an additional elec-

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trode beyond said grids and adapted to intercept said electron stream as it emerges from said cavity resonator, said grids being concentric with their respective cathode and having substantial cylindrical symmetry with respect to said cathode, all of said cathodes being electrically connected together, and said cavity resonators being electrically interconnected to cause oscillations generated in each of said sections to reinforce each other.

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