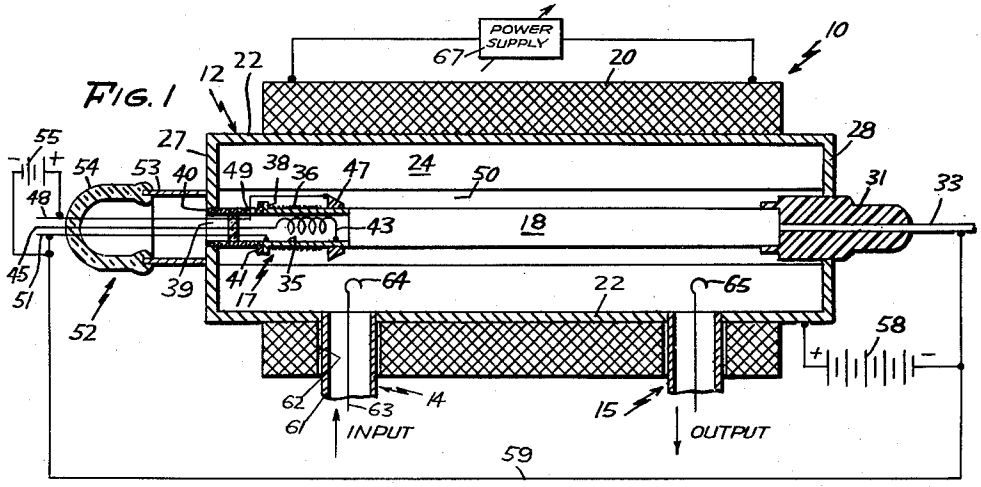
June 24, 1958 E. C. DENCH 2,840,757

ELECTRON DISCHARGE DEVICE

Filed March 20, 1957

FIG. 1



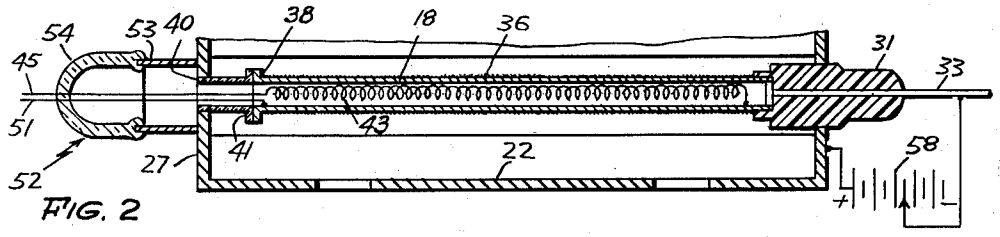


FIG. 2

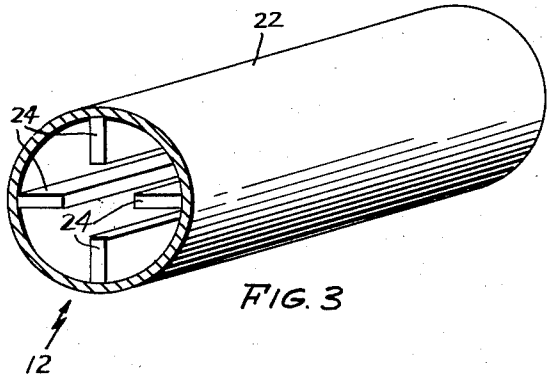


FIG. 3

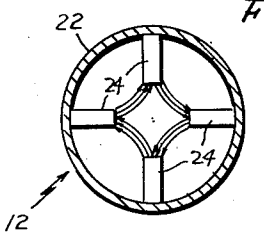


FIG. 4

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ELECTRON DISCHARGE DEVICE

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13 Claims. (Cl. 315—39.3)

This invention relates to an electron discharge device, and, more particularly, to a traveling wave amplifier in which substantial synchronism is maintained between the rotation of the radio frequency field of a loaded a slow wave transmission line and the rotation of a space charge in the region of said field.

The traveling wave tube, according to the invention, comprises a high frequency loaded energy transmission structure, such as a circular waveguide, with an elongated cylinder having an even number of radially-directed loading vanes equally spaced about the inner periphery of the waveguide. Such a waveguide is characterized in that the electric lines of force will be concentrated at the inner ends of the vanes and the electric field will appear to rotate about the longitudinal axis of the tube at an angular velocity, dependent upon the number of vanes and the frequency of operation.

An axial cathode is provided at the center of the loaded waveguide and the vanes are maintained at a positive direct current potential relative to the cathode. The tube further includes a magnetic field-producing means, such as a cylindrical magnet or solenoid, extending the length of the tube, for providing a longitudinal magnetic field in the space between the cathode and the vanes. Owing to the interaction of the electric field between cathodes and the loading (anode) vanes and the magnetic field transverse thereto, a rotating space charge may be obtained at several points along the length of the tube; the angular velocity of this rotating space charge can be controlled either by the potential of the vanes or the magnitude of the magnetic field or both. When the angular velocity of the space charge is adjusted to the proper values with respect to that of the radio frequency wave, amplification of input signals to the tube will result.

At frequencies higher than cut-off, the waveguide transmission structure will propagate over a wide range of frequencies.

One advantage of this system is that for a given number of vanes, as their inner radius is decreased, the required anode voltage may be lowered; a radius may be found so that reasonable anode voltages of the order of 10 kv. and less can be used.

Other objects and advantages of this invention will be apparent as the description thereof progresses, reference being had to the acompanying drawings wherein:

Fig. 1 is a longitudinal view in cross section of a traveling wave tube according to the invention;

Fig. 2 is a fragmentary sectional view of a modification of the tube shown in Fig. 1;

Fig. 3 is a perspective view of a portion of the transmission line or waveguide of Fig. 1; and

Fig. 4 is a diagram in transverse cross section of a portion of the transmission line of Fig. 1 showing the approximate electric field distribution in the transmission line of Figs. 1 and 3.

Referring now to the drawing, Fig. 1 illustrates an embodiment of a traveling wave amplifier **10** of the

invention, including a slow-wave electromagnetic energy-propagating structure **12** with an input connection **14** for inserting a signal to be amplified adjacent one end and an output connection **15** disposed in proximity with the other end. Tube **10** further includes an electron gun **17** disposed near one end of slow wave structure **12** and an elongated cathode member **18** centrally mounted within the tube. A longitudinal disposed coil **20** surrounding the propagating structure provides the necessary axial magnetic field to aid in directing an electron beam in the vicinity of the propagating structure.

As shown clearly in Fig. 3, the propagating structure **12** may be in the form of a long cylindrical member **22** having an even number of radially-disposed loading vanes **24** equally spaced about the inner periphery of cylindrical member **22**. Although the structure shown in Figs. 1, 2 and 4 contains four vanes, any even number of vanes may be used, whereupon a different mode of propagation along the structure exists.

The radius of the cylindrical space between vane tips may be altered within a considerable range; the smaller the radius, however, the lower becomes the voltage required between the vanes and the cathode, or other reference point. As shown in Fig. 1, the propagating structure may form a portion of the evacuated tube envelope which further includes circular end portions **27** and **28** hermetically sealed to member **22**.

The elongated cylindrical member **18**, which forms part of the cathode assembly, is affixed, as by brazing, at one end to an electrically-insulating bushing **31** inserted in end portion **28** of the tube envelope. An electrically-conductive lead **33** is connected to one end of cathode member **18** and extends through bushing **31**. A cathode sleeve **35** is attached to the opposite end of cathode member **18**; the periphery of sleeve **35** is coated with an electron-emissive material **36** and one end portion is upturned to form a flange **38**. A second sleeve **40** made of an electrically insulating material, such as glass, includes a flange portion **41** affixed to flange **38** of sleeve **35** and is secured to the end portion **27** of the tube envelope in the region of aperture **39** by any of the usual glass-to-metal sealing techniques.

The electron gun **17** includes also a heater **43** disposed within the cathode sleeve **35**; one end of the heater is secured to the cathode sleeve **35**, as shown in Fig. 1, and the other end of the heater is connected to heater lead **45**. Finally, the electron gun **17** includes an accelerating electrode **47** which serves to initiate the proper electron beam trajectory; the accelerating electrode **47** is connected to external circuitry by a circuit lead **48** passing through an aperture **49** in sleeve **40**. A cathode lead **51** is connected to cathode sleeve **35**. The cathode lead **51**, heater lead **45**, and accelerating electrode lead **48** are brought out of the tube through a vacuum-tight seal **52** including a metal sleeve **53** fastened to the end portion **27** of the tube and a glass tubulature sealed to sleeve **53** by a conventional glass-to-metal sealing technique. The accelerating electrode **47** is maintained positive with respect to the cathode sleeve **35** by means of a voltage source **55**.

The electrons emitted from the cathode sleeve **35**, after exposure to the effect of accelerating electrode **47**, are caused to enter the interaction space **50** between cathode member **18** and the propagating structure **22** disposed about the cathode member. These electrons encounter the perpendicularly-disposed electric and magnetic fields, the electric field between the anode or propagating structure **22** and the cathode member **18** being produced by the unidirectional potential source **58** connected between lead **33** and a portion of the propagating structure, such as the envelope portion **22**. As shown in Fig. 1, the

cathode sleeve 35 may be maintained at the same potential as the cathode member 18 by means of a lead 59 interconnecting cathode lead 51 and the negative terminal of potential source 58. As indicated in Fig. 2, potential source 58 may be made variable to obtain the required synchronization of the rotating electromagnetic field and the rotating electron beam. Alternately, the magnetic field strength may be varied as by adjustment of the source 67 shown in Fig. 1. By virtue of the action of the transverse electric and magnetic fields, the electrons in the space between the vanes 24 and the cathode member 18 rotate about the latter at several transverse planes along the axis of the tube.

The input coupling means 14 to the propagating structure 22 may consist of a coaxial line whose outer conductor 61 passes through an opening 62 in coil 20 and whose inner conductor 63 terminates in a coupling loop 64 positioned in the interaction space 50 between the propagating structure and cathode 18. Similarly, the output coupling means 15 positioned adjacent the other end of the tube includes a coupling loop 65, similar to the coupling loop 64. The invention should not be restricted to the particular type of coupling shown in Fig. 1, inasmuch as other types are available, such as waveguides, probes, etc.

As shown in Fig. 2, the active or thermionically-emissive portion of the cathode may be extended to include substantially all of the cathode element 18; in this case, the entire cathode element 18 is made hollow to receive heater wire 43. In the embodiment shown in Fig. 2, the accelerating electrode 47 of Fig. 1 may, in some instances, be omitted.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents 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 traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements disposed along the inner periphery of said member, a cathode spaced from said propagating structure, and means for directing electrons from at least a portion of said cathode in paths rotating about said cathode in substantial synchronism with the rotation of said fields.

2. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements disposed along the inner periphery of said member, a cathode spaced from said propagating structure and substantially coextensive with the loading elements, means for directing electrons from at least a portion of said cathode in paths rotating about said cathode in substantial synchronism with the rotation of said fields, said means for directing including a variable source of voltage connected between said cathode and said propagating structure for producing an electric field therebetween and a single axial field-producing means for producing a magnetic field transverse to said electric field.

3. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including a cylindrical electrically-conductive member and an even number of loading elements radially disposed about the inner periphery of said member, a cathode spaced from said propagating structure and substantially coextensive with the loading elements, and means for directing electrons from at least a portion of said cathode in paths rotating about said cathode in substantial synchronism with the rotation of said fields.

4. A traveling wave electron discharge device comprising a slow wave propagating structure having input and output terminals and constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements disposed about the inner periphery of said member, a cathode, and means for directing electrons from at least a portion of said cathode in energy-exchanging relationship with said wave fields.

5. A traveling wave electron discharge device comprising a slow wave propagating structure having input and output terminals and constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including a cylindrical electrically-conductive member and a plurality of loading elements radially disposed about the inner periphery of said member, a cathode substantially centrally positioned within said propagating structure and substantially coextensive with the loading elements, and means for directing electrons from at least a portion of said cathode in energy-exchanging relationship with said wave fields.

6. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including a cylindrical electrically-conductive member and a plurality of loading elements radially disposed about the inner periphery of said member, a cathode positioned within said propagating structure, and means for directing electrons from at least a portion of said cathode in energy-exchanging relationship with said wave fields by causing rotation of said electrons about said cathode in substantial synchronnism with the rotation of said fields.

7. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including a cylindrical electrically-conductive member and an even number of loading elements radially disposed about the inner periphery of said member, a cathode centrally positioned within said propagating structure and substantially coextensive with the loading elements, means for directing electrons from at least a portion of said cathode in energy-exchanging relationship with said wave fields by causing rotation of said electrons about said cathode in substantial synchronism with the rotation of said fields, said means for directing including means for producing an electric field between said cathode and said structure and including means for supplying a variable voltage between said cathode and said propagating structure and a single axial magnetic field-producing means for producing a magnetic field transverse to said electric field.

8. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including a cylindrical electrically-conductive member and an even number of loading elements

radically disposed about the inner periphery of said member, a cathode coated over substantially the entire surface thereof with an electron-emissive material, said cathode being centrally positioned within said propagating structure and substantially coextensive with the loading elements, and means for directing electrons from said cathode in energy-exchanging relationship with said wave fields.

9. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including a cylindrical electrically-conductive member and an even number of loading elements radially disposed about the inner periphery of said member, a cathode coated over substantially the entire surface thereof with an electron-emissive material, said cathode being positioned within said propagating structure and substantially coextensive with the loading elements, means for directing electrons from said cathode in energy-exchanging relationship with said wave fields, said means for directing causing rotation of said electrons about said cathode in substantial synchronism with the rotation of said fields.

10. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements disposed about said member, a cathode assembly spaced from said loading elements, said cathode assembly having an electron-emissive portion positioned near one end of said structure and accelerating means for causing electrons to enter the space between the remaining portion of said cathode assembly and said structure, and means for directing electrons from said cathode assembly in energy-exchanging relationship with said wave fields, said means for directing causing rotation of said electrons about said cathode assembly in substantial synchronism with the rotation of said fields.

11. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements disposed about said member, a cathode assembly spaced from said loading elements, said cathode assembly having an electron-emissive portion positioned near one end of said structure and accelerating means for causing electrons to enter the space between the remaining portion of said cathode assembly and said structure, and means for directing electrons from said cathode assembly in energy-exchanging relationship with said wave fields, said means

for directing including means for supplying a variable source of voltage between said cathode assembly and said propagating structure for varying the angular velocity of rotation of said electrons about said cathode in said wave fields.

12. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements radially disposed about said member, a cathode assembly spaced from said loading elements, said cathode assembly having an electron-emissive portion positioned near one end of said structure and accelerating means for causing electrons to enter the space between the remaining portion of said cathode assembly and said structure, and means for directing electrons from said cathode assembly in energy-exchanging relationship with said wave fields, said means for directing including means for producing an electric field between said cathode assembly and said structure and including means for supplying a variable source of voltage between said cathode and said propagating structure and a single axial magnetic field-producing means for producing a magnetic field transverse to said electric field.

13. A traveling wave electron discharge device comprising a slow wave propagating structure constructed to produce along a path adjacent thereto fields of electromagnetic wave energy being transmitted, said fields rotating about the longitudinal axis of said structure, said propagating structure including an elongated electrically-conductive member and an even number of loading elements disposed about said member, a cathode assembly spaced from said loading elements, said cathode assembly having an electron-emissive portion positioned near one end of said structure and accelerating means for causing electrons to enter the space between the remaining portion of said cathode assembly and said structure, and means for directing electrons from at least a portion of said cathode in energy-exchanging relationship with said wave fields by causing rotation of said electrons about said cathode in substantial synchronism with the rotation of said fields, said means for directing including means for producing an electric field between said cathode and said structure and including means for supplying a variable voltage between said cathode and said propagating structure and a single axial magnetic field-producing means for producing a magnetic field transverse to said electric field.

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