Jan. 26, 1960 L. BRÜCK 2,922,919

HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

Filed Feb. 24, 1953 2 Sheets-Sheet 1

FIG. 1

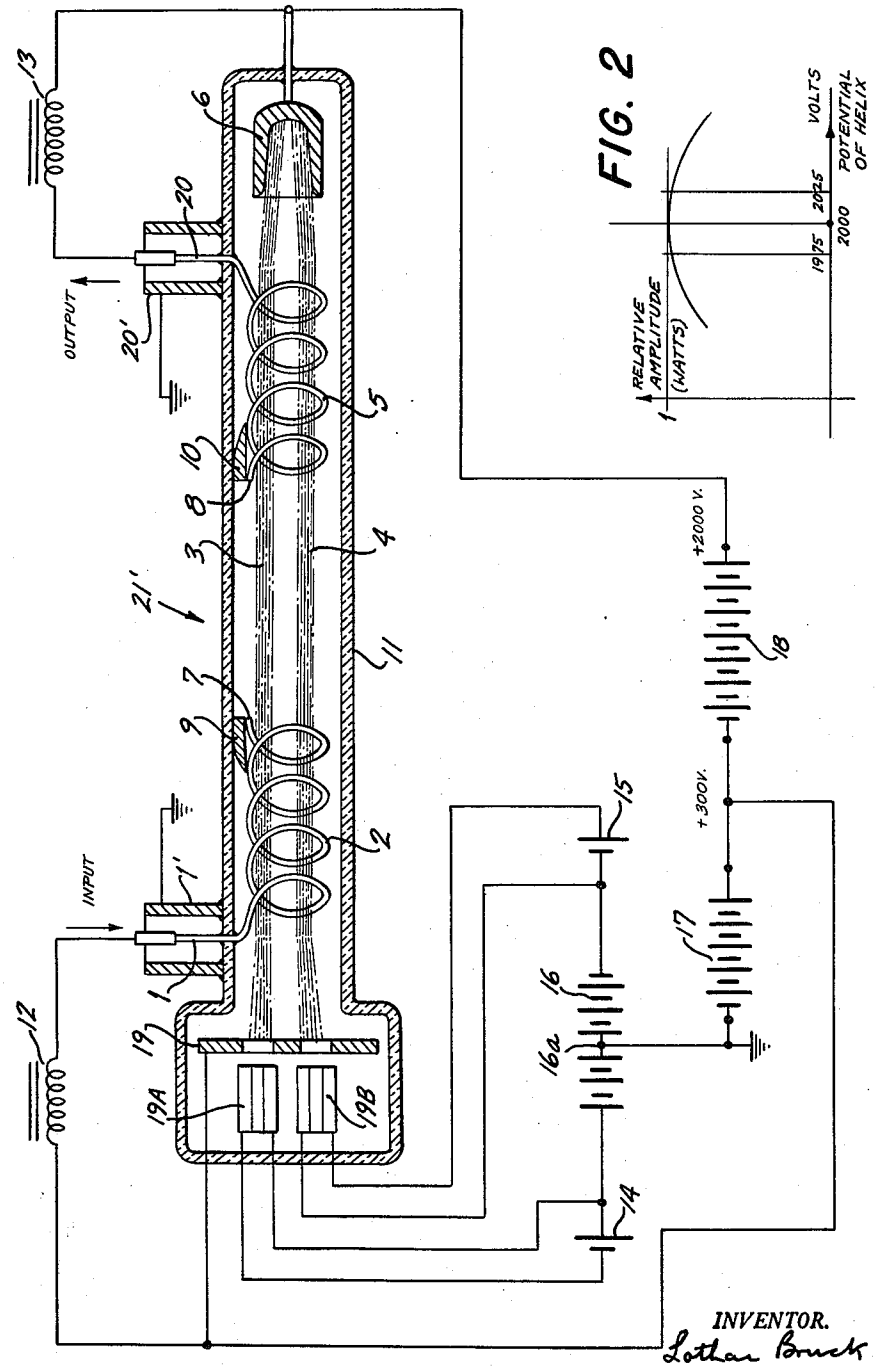


FIG. 2

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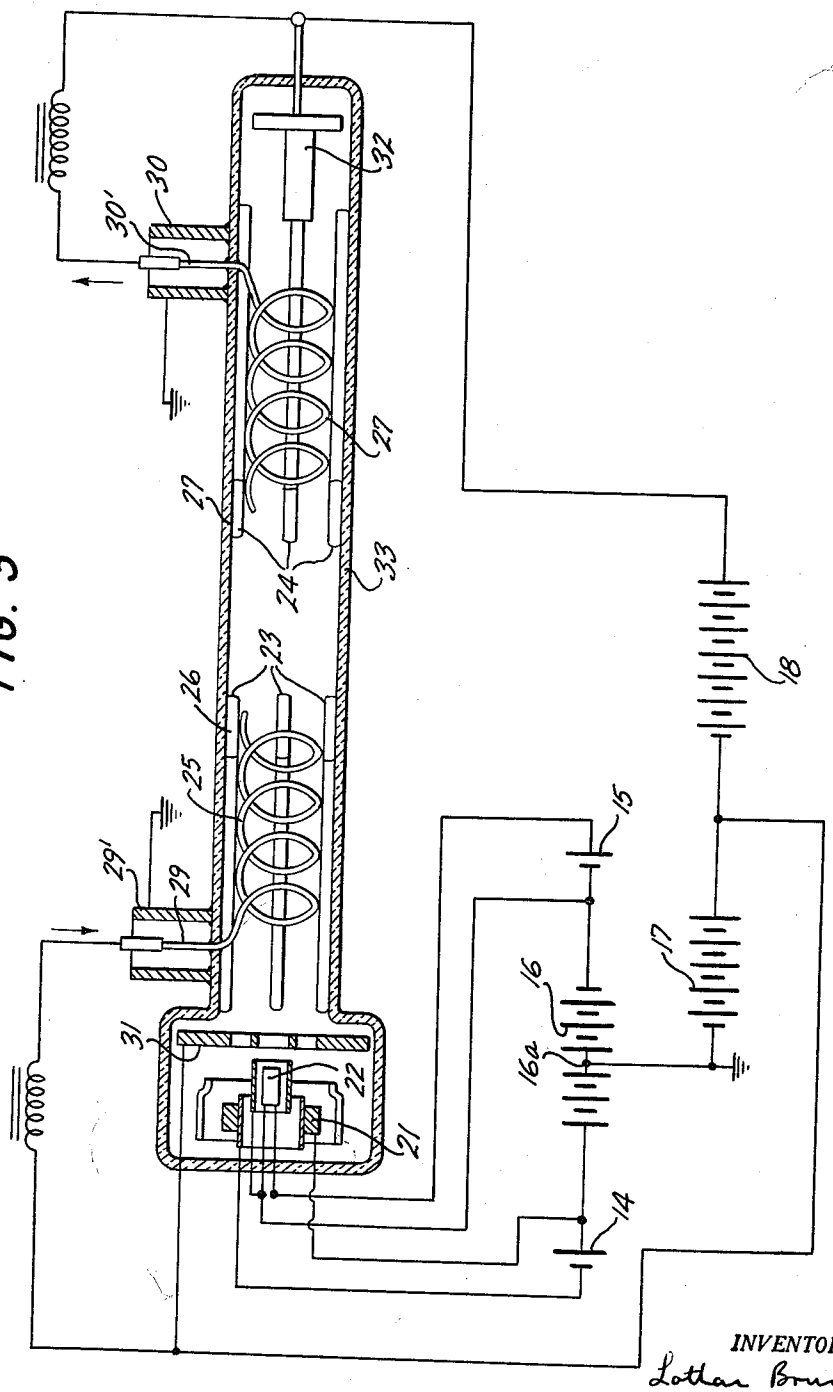
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2 Sheets-Sheet 2

FIG. 3



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HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

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Claims priority, application Germany February 25, 1952

13 Claims. (Cl. 315—3.6)

This invention relates to an electron discharge device for generating ultra-short frequencies, and in particular to a discharge device which comprises an electron wave tube section and a travelling wave tube section combined in one envelope.

The use of travelling wave tube for generating high power output levels is well known. It is also well known that certain intrinsic difficulties exist in the design of such a tube, these difficulties involving

(1) The manufacturing of a uniform helix winding;

(2) Maintaining the helix in axial alignment;

(3) Reducing the interception of the electron beam by the helix to a minimum, particularly at very high frequencies.

The electron wave tube is equally well known and involves the use of two electron beams having different velocities which have impressed thereon, by means of suitable electromagnetic circuits, high frequency signals to be amplified. While it is true that high voltage amplification may be obtained with the electron wave tube, the power output from such tubes is limited while the high voltage amplification is predominant.

It is therefore an object of this invention to provide a high frequency electron discharge device which utilizes the advantageous features of the electron and the travelling wave tubes.

It is another object of this invention to provide a high frequency discharge device which may be easily manufactured.

It is yet another object of this invention to eliminate the disadvantages associated with electron and travelling wave tubes and to utilize the best features thereof.

With the above objects in view the present invention consists mainly of an electron discharge device for generating ultra-short frequencies, comprising in combination, a vacuum tight envelope, a first and a second electron beam emitting means located in the envelope, emitting two electron beams having different velocities, collector means located in the envelope, the collector being arranged opposite to and spaced from the first and second electron emitting means to define a common path for the electron beams, input delay line means arranged in the region of the common path of the electron beams after the same has been emitted by the electron emitting means, the input delay means adapted to be coupled to signal waves to be amplified so as to velocity modulate the electron beams, output delay line means having a pre-determined dimension, the output delay line means being arranged in the region of the path of the electron beams subsequent to and spaced from the input delay line means, so as to leave between the input and output delay line means a field free region wherein the velocity modulated electron beams are transformed to density modulated electron beams, a voltage source connected to the output delay line means, the voltage source applying such a potential to the output delay line so that the output delay line due to its predetermined dimension and the potential applied thereto

acts as a travelling wave tube section, having a signal wave excited therein whose propagating velocity along the section is equal to the electron beam velocity passing therethrough.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantage thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 illustrates schematically a high frequency discharge device constituting one form of the invention;

Fig. 2 illustrates a curve showing the relative amplitude versus electron volts in the output section of this high frequency discharge device; and

Fig. 3 illustrates a modification of the invention wherein two electron beams are generated, one of these beams surrounding the other.

Referring to Figure 1, a high-frequency discharge tube **21'** is shown, into which is introduced through its input connector **1, 1'** a signal to be amplified. The outer conductor **1'** of the input coax connector is vacuum sealed to the glass envelope **11** of the discharge device, the center conductor **1** of the input connector being connected through a vacuum seal in the envelope to the input end of the helix or delay transmission line **2**. At the opposite end **7** of the delay line **2** is connected a matched attenuator **9** in order to prevent reflection of the input signal in the event of a mismatch. An output connector **20, 20'** is vacuum sealed at its outer conductor **20'** to the glass envelope **11**, its inner conductor being connected through a vacuum seal in the envelope to the output end of a second helix, or a delay transmission line **5**. At the opposite end **8** of the helix **5** is connected a matched attenuator **10** to prevent reflection of amplified signals from the output toward the input end of the tube. Electron streams **3** and **4** are emitted by cathodes **19A** and **19B** respectively. The filaments of cathodes **19A** and **19B** are connected to voltage source **14** and **15**. Between voltage source **14** and **15** is connected a voltage source **16** in such manner that cathode **19B** will be at a higher potential than cathode **19A** with respect to the common return point **16***a*. Under these conditions the electron stream emitted by cathode **19B** will have a higher velocity than the electron stream emitted by cathode **19A**. Another voltage source **17** is connected at one of its terminals to the source **16** at point **16***a*, which is the mid-voltage point of source **16**, the other terminals of voltage source **17** being connected to the accelerating anode **19**. The input side of delay transmission line **2**, is connected to the accelerating anode, **19**, and voltage source **17**, via a radio frequency choke **12**. This choke is used to prevent any high-frequency signals from reaching the D.C. voltage source. Voltage source **18** is connected in series with voltage source **17** at one terminal thereof, and at the other terminal thereof to a collector **6**. The collector **6** in turn is connected to the inner conductor **20** of the output connector via radio frequency choke **13**, thereby placing the helix or delay line **5**, at the same potential as the collector **6**. The voltage output of source **18** is approximately 2000 volts positive with respect to cathodes **19***a* and **19***b*. It is to be understood that this voltage is of course merely illustrative, and is not to be construed as a limitation of the invention.

The operation of the discharge device illustrated in Figure 1 is as follows:

A high frequency signal introduced at the connector **1, 1'** is fed to the input end of the delay line **2**. This input signal will be impressed on each of the electron

streams 3, 4, by means of the delay line 2, thereby velocity modulating the same. The electron streams having different average velocities upon becoming density modulated interact so as to produce an amplified wave. The delay line 2, as noted, is used to impress a signal on the electron streams, the amplification, however, taking place in the electron flow itself. The important factor in the interaction is the electric field, which stores energy and acts on the electrons, and the electrons themselves. The charge of the electrons produces the electric field; the mass of the electrons, and their kinetic energy, serve as do inductances and magnetic stored energy in electromagnetic propagation. In electron wave tubes it is customary to use relatively low voltages for accelerating the electrons in an electron stream which produces, as a result, low beam current, thereby yielding only a relatively low power output. The weak beam current is acted upon by the impressed high frequency signal which interacts therewith, thereby creating strong modulation of the beam. In the field free region, between delay lines 2 and 5, the electrons become density modulated by virtue of the faster electrons overtaking the slower electrons and forming concentrated bunches. The electron streams 3, 4 emitted by cathodes 19A and 19B respectively, after passing through the field free region come under the influence of the high potential connected to helix 5 and collector 6. As a result of the high potential at helix 5 and collector 6, the variation in velocity of the electrons in electron streams 3, 4 become practically insignificant, so that the section of the discharge tube including helix 5, attenuation layer 10, and collector 6 acts as a travelling wave amplifier. To insure the operation of this section of the tube as a travelling wave tube, the length, the dimensions (pitch and diameter) and the propagation conditions are fixed so that the waves excited in this section of the tube by electron streams 3, 4 will propagate at the same velocity as the electron streams 3, 4 passing therethrough.

Figure 2 illustrates in graphic form why the output section of the high-frequency discharge device 21', operates as a travelling wave tube. In this figure, the relative amplitude in watts is plotted against electron volts. The electron velocity difference of 50 volts is seen to become insignificant under the influence of the 2000 volts connected to the delay line 5 and collector 6.

As stated the attenuation layers 9 and 10 prevent high frequency signals from being reflected beyond the ends 7, 8 of delay lines 2, 5, respectively, in the event of any mismatches in the tube. In order to reduce the effect of the attenuation layers on the electron streams 3, 4, it is also possible to gradually increase the diameter and pitch of the helices in the vicinity of ends 7, 8 and use a ceramic wedge coated with an aquadag suspension to eliminate high-frequency signal reflections. The remaining part of the helix may be wound uniformly. It is of course to be understood that the delay line is not limited to the use of a conductor wound into a helical form but includes all high frequency structures capable of reducing the phase velocity of high frequency waves propagated thereby. Examples of some of these well known delay structures, are for instance, periodically loaded lines involving capacitive or inductive loading or made of circular links.

Figure 3 illustrates a modification of the invention described in relation to Figures 1 and 2.

In this figure, unlike Fig. 1, where the cathodes were disposed side by side resulting in two electron streams moving alongside each other, cathode 22 is centrally located in relation to cathode 21. Cathode 21 is designed to emit a hollow beam (not shown) which encircles the beam emitted by cathode 22 (not shown). These electron beams are collected at collector 32. Delay lines 25 and 27 are supported by means of rods 23 and 24 respectively. These rods are provided at one end thereof with attenuation layers 26, 28, respectively, which serve to prevent micro-wave signal reflections. The voltage sources 14, 15, 16, 17 and 18 are connected in the same manner as they were in the embodiment described in relation to Figure 1. The same potentials for explanatory purposes are applied in this embodiment to the accelerating anode 31 and to the collector as in the embodiment illustrated in Figure 1. An input connector 29, 29' is illustrated, the outer conductor of which, is joined to the glass envelope 33, the inner conductor of which is connected through a vacuum seal in the envelope, to the input end of the delay line 25. An output connector 30, 30' is likewise connected to the glass envelope 33 at its outer conductor, its inner conductor being connected similarly through a vacuum seal in the envelope to the output end of delay line 27.

The potential and the size of the output delay line are again chosen, according to the invention, so that the delay line section 27 operates as a travelling wave tube section. The operation of the embodiment illustrated in Figure 3 is similar to the operation described in relation to Figure 1. The advantage of the arrangement illustrated in Figure 3 arises from the closer contact between the two electron streams (not shown), emitted by cathodes 21, 22, thereby resulting in greater interaction.

I claim:

1. An electron discharge device for generating ultrashort frequencies, comprising in combination, a vacuum tight envelope; a first and a second electron beam emitting means located in said envelope, emitting two electron beams having different velocities; collector means located in said envelope, said collector being arranged opposite to and spaced from said first and second electron emitting means to define a common path for said electron beams; input delay line means arranged in the region of said common path of said electron beams after the same has been emitted by said electron emitting means, said input delay means adapted to be coupled to signal waves to be amplified so as to velocity modulate said electron beams; output delay line means arranged in the region of said path of said electron beams subsequent to and spaced from said input delay line means, so as to leave between said input and output delay line means a field free region acting as a traveling wave tube section causing predominantly voltage amplification wherein the velocity modulated electron beams are transformed to density modulated electron beams; a voltage source connected to said output delay line means for applying a direct potential thereto which is substantially higher than the potential of said input delay line in such manner that said output delay line means acts as a traveling field tube section causing predominantly power amplification and a signal wave excited therein is propagated therealong at a velocity approximately equal to the electron beam velocity passing therethrough.

2. An electron discharge device for generating ultrashort frequencies, comprising, in combination, a vacuum tight envelope; a first and a second electron beam emitting means located in said envelope, emitting two electron beams having different velocities; collector means located in said envelope, said collector being arranged opposite to and spaced from said first and second electron emitting means to define a common path for said electron beams; an input helix arranged in the region of said common path of said electron beams after the same has been emitted by said electron emitting means, said input helix adapted to be coupled to signal waves to be amplified so as to velocity modulate said electron beams and to act as a traveling wave tube section causing predominantly voltage amplification; an output helix having a predetermined dimension, said output helix being arranged in the region of said path of said electron beams subsequent to and spaced from said input helix, so as to leave between said input and output helices a field free region wherein the velocity modulated electron beams are transformed to density modulated electron beams and amplify

said signal waves; a voltage source connected to said output helix for applying a direct potential thereto which is substantially higher than that of said input helix in such manner that said output helix acts as a travelling field tube section causing predominantly power amplification and a signal wave excited therein is propagated therealong at a velocity substantially equal to the electron beam velocity passing therethrough.

3. An electron discharge device for generating ultra-short frequencies, comprising, in combination, a vacuum tight envelope; a first and a second electron beam emitting means located in said envelope, emitting two electron beams having different velocities; collector means located in said envelope, said collecor being arranged opposite to and spaced from said first and second electron emitting means to define a common path for said electron beam; input delay line means arranged in the region of said common path of said electron beams after the same has been emitted by said electron emitting means, said input delay means adapted to be coupled to signal waves to be amplified so as to velocity modulate said electron beams and to act as a traveling wave tube section causing predominantly voltage amplification; output delay line means having a predetermined dimension, said output delay line means being arranged in the region of said path of said electron beams subsequent to and spaced from said input delay line means, so as to leave between the adjacent ends of said input and output delay line means a field free region wherein the velocity modulated electron beams are transformed to density modulated electron beams; attenuating means connected at the adjacent ends of said input and output delay line means to prevent intercoupling of said input and output delay lines; a voltage source connected to said output delay line means for applying a direct potential thereto which is substantially higher than the potential of said input delay line means in such manner that said output delay line due to its predetermined dimension and the potential applied thereto acts as a travelling wave tube section causing predominantly power amplification, and a signal field excited therein is propagated therealong at a velocity substantially equal to the electron beam and amplify said signal waves velocity passing therethrough.

4. An electron discharge device for generating ultra-short frequencies, comprising, in combination, a vacuum tight envelope, a first electron emitting means; a second electron emitting means arranged in coaxial relation to said first electron emitting means, said first and second electron emitting means located in said envelope and emitting two electron beams having different velocities, one of said electron beams propagating within the other; collector means located in said envelope, said collector being arranged opposite to and spaced from said first and second electron emitting means to define a common path for said electron beams; input delay line means arranged in the region of said common path of said electron beams after the same has been emitted by said electron emitting means, said input delay means adapted to be coupled to signal waves to be amplified so as to velocity modulate said electron beams and to act as a traveling wave tube section causing predominantly voltage amplification; output delay line means arranged in the region of said path of said electron beams subsequent to and spaced from said input delay line means, so as to leave between said input and output delay line means a field free region wherein the velocity modulated electron beams are transformed to density modulated electron beams and amplify said signal waves; a voltage source connected to said output delay line means for applying a direct potential thereto which is substantially higher than the potential of said input delay line in such manner that said output delay line acts as a travelling field tube section causing predominantly power amplification and a signal wave excited therein travels therealong at a velocity approximately equal to the electron beam velocity passing therethrough.

5. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of charged particles lengthwise of said path at different velocities; velocity modulation means located near said one end of said elongated closer acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of charged particles with a signal it is desired to amplify, whereby said modulated pair of streams of charged particles interact with one another to produce amplification; travelling field means causing predominantly power amplification spaced from said velocity modulation means and located near the other end of said elongated closure, said travelling field means having a substantially higher potential than said velocity modulation means for accellerating substantially said pair of streams of charged particles and for deriving from said accelerated streams of charged particles a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

6. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of electrons lengthwise of said path at different velocities; velocity modulation means located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of electrons with a signal it is desired to amplify, whereby said modulated pair of streams of electrons interact with one another to produce amplification; traveling field means causing predominantly power amplification spaced from said velocity modulation means and located near the other end of said elongated closure, said travelling field means having a substantially higher potential than said velocity modulation means for accelerating substantially said pair of streams of electrons and for deriving from said accelerated streams of electrons a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

7. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of charged particles lengthwise of said path at different velocities; velocity modulation means including delay line means located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of charged particles with a signal it is desired to amplify, whereby said modulated pair of streams of charged particles interact with one another to produce amplification; traveling field means causing predominantly power amplification including delay line means spaced from said velocity modulation means and located near the other end of said elongated closure, said travelling field means having a substantially higher potential than said velocity modulation means for accelerating substantially said pair of streams of charged particles and for deriving from said accelerated streams of charged particles a slow electromagnetic wave having a velocity in the direction of

movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

8. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of charged particles lengthwise of said path at different velocities; velocity modulation means including a helix of wire concentrically arranged with respect to the path traveled by said streams of charged particles and located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of charged particles with a signal it is desired to amplify, whereby said modulated pair of streams of charged particles interact with one another to produce amplification; traveling field means causing predominantly power amplification including a helix of wire concentrically arranged with respect to the path traveled by said streams of charged particles, spaced from said velocity modulation means and located near the other end of said elongated closure, said helix of wire of said travelling field means being at a substantially higher potential than said helix of wire of said velocity modulation means for accelerating substantially said pair of streams of charged particles and for deriving from said accelerated streams of charged particles a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

9. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of charged particles lengthwise of said path at different velocities; velocity modulation means including delay line means located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of charged particles with a signal it is desired to amplify, whereby said modulated pair of streams of charged particles interact with one another to produce amplification; means for maintaining said delay line means at a given potential; traveling field means causing predominantly power amplification including delay line means spaced from said velocity modulation means and located near the other end of said elongated closure; means for maintaining said last-named delay line means at a potential substantially more positive than that of said first-named delay line means for accelerating substantially said pair of streams of charged particles and for deriving from said accelerated streams of charged particles a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

10. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of electrons lengthwise of said path at different velocities; velocity modulation means including a helix of wire concentrically arranged with respect to the path traveled by said streams of charged particles and located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of electrons with a signal it is desired to amplify, whereby said modulated pair of streams of electrons interact with one another to produce amplification; traveling field means causing predominantly power amplification including a helix of wire concentrically arranged with respect to the path traveled by said streams of charged particles, spaced from said velocity modulation means and located near the other end of said elongated closure, said helix of wire of said travelling field means being at a substantially higher potential than said helix of wire of said velocity modulation means for accelerating substantially said pair of streams of electrons and for deriving from said accelerated streams of electrons a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

11. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of charged particles lengthwise of said path at different velocities; velocity modulation means located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of charged particles with a signal it is desired to amplify, whereby said modulated pair of streams of charged particles interact with one another to produce amplification; traveling field means causing predominantly power amplification spaced from said velocity modulation means and located near the other end of said elongated closure, said travelling field means having a substantially higher potential than said velocity modulation means for accelerating substantially said pair of streams of charged particles and for deriving from said accelerated streams of charged particles a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; attenuation means operatively associated with said velocity modulation means and said traveling field means for preventing intercoupling of said two means; and means coupled to said traveling field means for deriving therefrom an amplified signal.

12. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of charged particles lengthwise of said path at different velocities; velocity modulation means including a helix of wire concentrically arranged with respect to the path traveled by said streams of charged particles and located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of charged particles with a signal it is desired to amplify, whereby said modulated pair of streams of charged particles interact with one another to produce amplification; traveling field means causing predominantly power amplification including a helix of wire concentrically arranged with respect to the path traveled by said streams of charged particles, spaced from said velocity modulation means and located near the other end of said elongated closure, said helix of wire of said travelling field means being at a substantially higher potential than said helix of wire of said velocity modulation means for accelerating substantially said pair of streams of charged particles and for deriving from said accelerated streams of charged particles a slow electro-

magnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; attenuation means located at the ends adjacent one another of said two helices of wire for preventing intercoupling of said velocity modulation means and said traveling field means; and means coupled to said traveling field means for deriving therefrom an amplified signal.

13. An electron discharge device comprising, in combination, an elongated closure defining a path of travel for a stream of charged particles; electrode means located at one end of said closure for directing a pair of closely coupled streams of electrons, one concentric with the other, lengthwise of said path at different velocities; velocity modulation means located near said one end of said elongated closure acting a traveling wave tube section causing predominantly voltage amplification for velocity modulating said pair of streams of electrons with a signal it is desired to amplify, whereby said modulated pair of streams of electrons interact with one another to produce amplification; traveling field means causing predominantly power amplification spaced from said velocity modulation means and located near the other end of

said elongated closure, said travelling field means having a substantially higher potential than said velocity modulation means for accelerating substantially said pair of streams of electrons and for deriving from said accelerated streams of electrons a slow electromagnetic wave having a velocity in the direction of movement of said streams substantially equal to that of said streams, whereby said streams and slow electromagnetic wave interact to produce amplification; and means coupled to said traveling field means for deriving therefrom an amplified signal.

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