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ELECTRON DISCHARGE DEVICE
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Fig. 1.

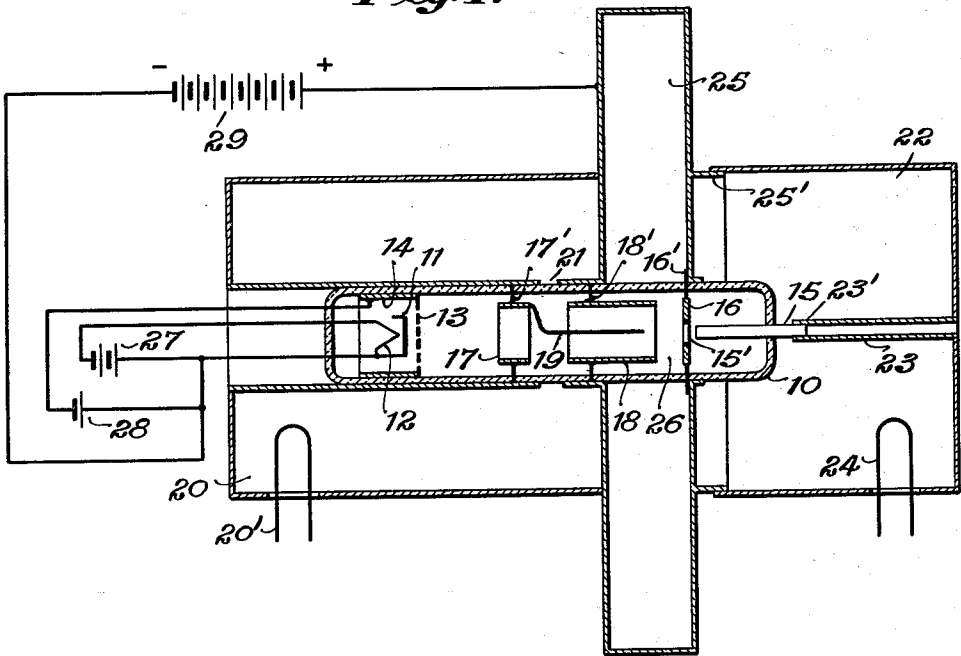
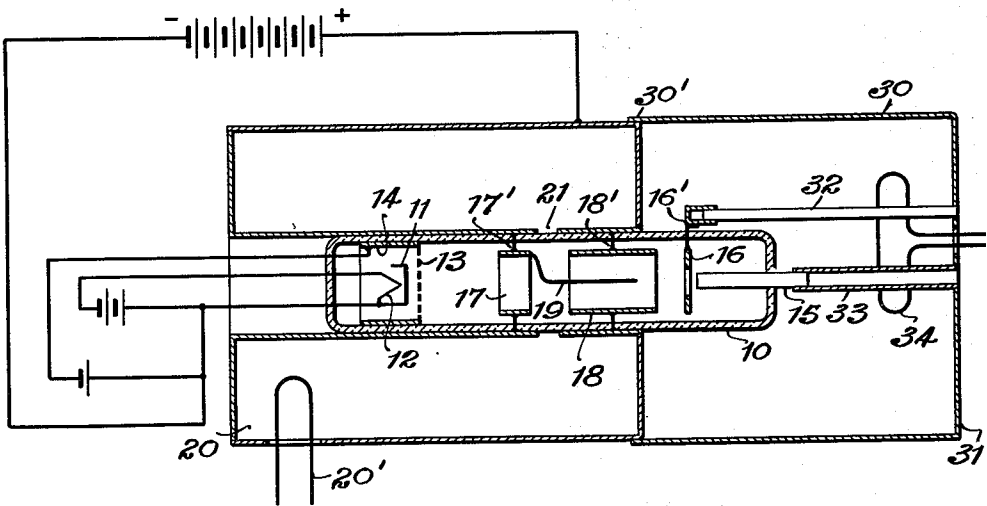


Fig. 2.



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ELECTRON DISCHARGE DEVICE

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25 Claims. (Cl. 250—27.5)

My invention relates to electron discharge devices, more particularly to such devices useful at ultra high frequencies.

Recently there has been developed what has been termed "velocity modulation" for use at ultra high frequencies. In the arrangements proposed the electrons of an electron beam or stream are given varying velocities, the variation of velocity being applied cyclically so that the beam comprises slow and fast electrons. As a result, at a predetermined point fast electrons overtake the slow electrons, thus causing groups or bunching. When groups have been bunched, it is possible to extract energy from the beam by proper electrode arrangements either inductively or by absorption by absorption electrodes. The method of producing slow and fast electrons in a beam has proven particularly useful at ultra high frequencies.

It is, therefore, an object of my invention to provide an electron discharge device suitable for use at ultra high frequencies and particularly such a tube depending upon cyclically varying the velocity of the electrons in the electron stream.

It is another object of my invention to separate the fast and slow electrons in space and to utilize the two groups of electrons to excite an output system of an electron discharge device made according to my invention.

It is a further specific object of my invention to provide such a device which may be operated in the manner of a push-pull electron discharge device.

It is a still further object of my invention to provide an improved form of such an electron discharge device utilizing resonant cavities for modulating the electron stream and for extracting energy from the stream.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 is a diagrammatic longitudinal section of an electron discharge device and associated circuit made according to my invention, and Figure 2 is a diagrammatic longitudinal section of a modification of an electron discharge device made according to my invention.

Briefly in a tube made according to my invention I provide an envelope containing at one end a cathode system for supplying a stream of electrons and an output or collector electrode system

at the other end of the envelope. Positioned between the cathode and collector electrode systems are electrodes surrounding the discharge path and spaced by a gap in a plane transverse to the electron stream. A resonant cavity tank circuit which provides the input circuit surrounds the pair of electrodes within the tube envelope. This pair of electrodes is especially designed for separating the fast and slow electrons, both radially and longitudinally, into two groups of electrons. These two electron groups are directed to two different collector or output electrodes connected to opposite ends of a resonant cavity output system. Intermediate the input or modulating resonant cavity and the output resonant cavity may be positioned a third resonant cavity for insuring proper phasing of the electron stream or groups of electrons with the radio frequency fields of the resonant cavities for extraction of the energy from the grouped electrons. Thus the electron stream moving from the cathode to the collector electrodes, by velocity modulation is broken up into groups of fast and slow electrons. The groups are separated radially and longitudinally and directed in proper phase relationship to one or the other of the output electrodes incorporated in a resonant cavity output system.

In a modification a Lecher wire system connected to the output electrodes may be employed for extracting energy from the two groups of electrons in push-pull fashion.

Referring to Figure 1, the electron discharge device is provided with an elongated envelope 10 having at one end thereof a cathode 11, which may be indirectly heated by means of the heater 12. This cathode assembly is surrounded by a grid 13 provided with a collar 14 positioned closely adjacent the envelope wall. Positioned at the other end of the envelope are the collecting electrodes 15 in the form of a rod and 16 in the form of a ring, having connected thereto radial leads 16' for purposes to be described. Positioned between these two electrodes are modulating electrodes 17—18 spaced by a gap, both being supported by radial leads 17'—18' extending through the wall of the envelope for purposes to be described. The electrode 17 is provided with the rod 19 which extends within the electrode 18 axially thereof. Positioned on the outside of the envelope and surrounding the electrodes and grid and cathode is the resonant cavity or hollow resonator 20 provided with gap 21 registering with the gap between electrodes 17 and 18. This resonant cavity with the electrodes forms the

modulating portion of the electron discharge device and operates in a manner to be described. The portions of the resonant cavity tank adjacent the gap function as separated electrodes connected into the tank circuit.

Connected to the output electrodes 15 and 16 is the output resonant cavity 22 slidably connected to the output electrode 15 by the tubular extension 23 at 23' and with the collar 25' on the resonant cavity 25 also surrounding the tube envelope and positioned between the input resonant cavity 20 and output resonant cavity 22. This permits tuning for optimum output conditions. The end of the electrode 15 is retracted within the resonant cavity formed by the members 15, 22, 25', wall of resonator 25, radial leads 16' and electrode 16, thus providing a gap 15' between the electrode 16 and the rod electrode 15.

The control voltage is fed to the resonator 20 by means of coupling loop 20' and output extracted from the resonator 22 by means of coupling loop 24. Suitable sources of voltage for providing the heating current, the grid bias and the collector and resonant cavity voltages are indicated at 27, 28 and 29.

A focused beam of electrons is provided by means of cathode and grid 11-13 and directed axially of the tube to collector electrodes 15-16. In passing across the gap between electrodes 17 and 18, which registers with the gap 21 in the resonant cavity, the electrons are subjected to an ultra high frequency field transverse to the direction of flight of the electrons. The electrons in passing the gap are either accelerated or decelerated, depending upon whether or not the electrons enter a field which increases their velocity or decreases their velocity. Thus the fast and slow electrons are separated 180° in phase.

Specifically, if electrons are accelerated when passing across the gap, electrode 18 will be at a higher potential than electrode 17, but the rod 19 will be at a lower potential than the electrode 18. As a result the fast electrons in moving into the electrode 18 encounter an outwardly directed radial field, causing fast electrons to move out toward the surface of the electrode 18. These electrons are received by electrode 16. If the electrons are decelerated, electrode 17 is at a higher potential than electrode 18, the rod 19 now being at a higher potential. Thus electrons encounter an inwardly directed radial field causing decelerated electrons to move toward the rod electrode. As a result this concentrated group of electrons is received by the end of the electrode 15 substantially 180° later than the electrons on the electrode 16. In passing across the gap 26 the accelerated electrons are subjected to a retarded field delivering energy to the resonant cavity 25. Some energy is also delivered to the resonant cavity 22, 180° later when the slow electrons pass across the gap 26 they are accelerated by the radio frequency field between the end of the electrode 18 and the ring member 16, but due to the fact that they are concentrated toward the axis of the tube they pass across the gap 15' into the cavity 22, being collected by the electrode 15. However, the phase relationship is such that these electrons are decelerated in passing across the gap 15, giving up energy to the resonant cavity 22. Thus substantially all of the energy in the initially accelerated group of electrons can be delivered to the decelerated group of electrons and the pulse of the output voltage in-

tensified so that while the average output current remains the same it is possible to obtain a pulse of greater intensity than would otherwise result. Due to the enlarged surface extending inside and outside of the envelope wall, considerable capacity coupling exists between electrodes 14 and 17 and the inside tubular wall of the resonant cavity surrounding the outside of the tube so that substantially all radio frequency energy is bypassed by capacity coupling. Thus substantially no radio frequency voltages exist between grid 13 and electrode 17. The radial leads 17' and 18' supporting electrodes 17 and 18 also provide the D. C. potential and the low loss high frequency lead arrangement. The large diameter of the member 15 reduces to a considerable extent any losses which would occur if the usual small leads were used through the glass wall of the tube envelope.

Referring to Figure 2, the input system is substantially that shown in Figure 1, the same numerals indicating the same elements. However, the output system in the arrangement shown in Figure 2 comprises a Lecher wire system in which the rod 32 forming one conductor of the system is slidably connected and supported in a cup-shaped extension 16' connected to electrode 16 and the rod 33 is slidably coupled with the extended end 15 of the electrode by means of the collar. The output coupling loop 34 may be extended through an aperture in the shielding arrangement 31, which prevents radiation directly from the Lecher wire system. The shielding arrangement 31 may also be provided with a sliding fit 30' in order to provide easy application of the radiating system and also tuning of the Lecher wire system.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge device having a cathode for supplying a stream of electrons and a plurality of collectors in the path of the stream for receiving said electrons, means for cyclically varying the velocity of the electrons in said stream and including a pair of electrodes surrounding the path of said stream and spaced axially and providing a gap surrounding the path of said electron stream between the cathode and collectors, and means including a rod-like element supported by one of said electrodes and extending within the other of said electrodes for subjecting the stream of electrons to alternating radial electrostatic fields after cyclically varying the velocity of the electrons for directing the electrons to one or the other of said collectors.
2. An electron discharge device having a cathode for supplying a stream of electrons and a plurality of collectors for receiving said electrons, means for cyclically varying the velocity of the electrons in said stream including a pair of electrodes surrounding the path of said stream and spaced axially and providing a gap surrounding said electron path between the cathode and collectors, and means carried by one of said electrodes extending axially within the other elec-

trode for subjecting the electron stream to alternating radial electrostatic fields after cyclically varying the velocity of the electrons for directing the electrons to one or the other of said collectors.

3. An electron discharge device having a cathode for supplying a stream of electrons, and a plurality of collectors for receiving said electrons, means for modulating said electron stream and including a resonator having a pair of electrode elements surrounding the path of said stream and spaced axially and providing a gap surrounding said electron stream between the cathode and collectors, and means carried by one of said electrode elements extending axially within the other electrode element for subjecting said stream of electrons to alternating radial fields after said stream of electrons has been modulated to direct electrons to one or the other of said collectors.

4. An electron discharge device having an elongated envelope containing at one end a cathode for supplying a stream of electrons, and a pair of collector electrodes at the other end, a pair of electrodes positioned between the cathode and collector electrodes and spaced axially and providing a gap, a rod element carried by one of said pair of electrodes and extending coaxially within the other of said pair of electrodes, a resonator surrounding said envelope and having a gap registering with the gap between the pair of electrodes within said envelope, and a second resonator connected between said collector electrodes and surrounding the collector electrodes end of said envelope.

5. An electron discharge device having an elongated envelope containing at one end a cathode for supplying a stream of electrons, and a pair of collector electrodes at the other end, a pair of electrodes positioned between the cathode and collector electrodes and spaced axially to provide a gap, a rod element carried by one of said pair of electrodes and extending coaxially within the other of said pair of electrodes, a resonator surrounding said envelope and having a gap registering with the gap between the pair of electrodes within said envelope and providing an input circuit, and a second resonator connected between said collector electrodes and surrounding the collector end of said envelope and providing an output tank circuit, and a third resonator surrounding the envelope and positioned between the input and output resonators.

6. An electron discharge device having an elongated envelope containing at one end a cathode for supplying electrons, and collector electrodes positioned at the other end of said envelope for receiving said electrons, said collector electrodes including a ring-shaped electrode and a rod electrode positioned coaxially with said ring-shaped electrode, a pair of tubular electrodes positioned between the cathode and collector electrodes and spaced axially and providing a gap between said tubular electrodes, one of said tubular electrodes being provided with a rod element extending within and coaxial of the other tubular electrode.

7. An electron discharge device having a cathode for supplying a stream of electrons, and an output electrode system for receiving said electrons, said output electrode system including a resonator provided with a central aperture and an axially positioned member, the end of which registers with said aperture, and electrode means positioned between the cathode and output elec-

trode system and comprising a pair of tubular conductors spaced axially and providing a gap surrounding the path of the electron stream, one of said tubular conductors being provided with a rod-like extension positioned coaxially of and within the other tubular conductor.

8. An electron discharge device having a cathode for supplying a stream of electrons, and an output electrode system for receiving said electrons, said output electrode system including a resonator provided with a central aperture and an axially positioned member, the end of which registers with said aperture, and electrode means positioned between the cathode and output electrode system and comprising a pair of tubular electrodes spaced axially and providing a gap surrounding the path of the electron stream, one of said tubular electrodes being provided with a rod-like extension positioned coaxially of and within the other tubular electrode, and a resonator surrounding said cathode and tubular electrodes and having a gap registering with the gap between said tubular electrodes, and a resonator positioned between the input and output resonator.

9. An electron discharge device having an elongated envelope and containing at one end a cathode for supplying a stream of electrons, and a pair of collector electrodes at the other end of said envelope, said collector electrodes comprising a ring transverse to the longitudinal axis of said envelope, and a rod-like electrode extending axially of the envelope and positioned coaxially of said ring electrode, a pair of tubular electrodes positioned between the cathode and collector electrodes, the tubular electrode adjacent the cathode having a rod-like element extending within and coaxially of the other tubular electrode, said tubular electrodes and said ring-like electrode being provided with radially directed conductors extending through the wall of the envelope, an input resonator closely surrounding said envelope and having a gap registering with the gap between said tubular electrodes and electrically contacting the radially directed conductors of said tubular electrodes, and an output resonator surrounding the collector end of the envelope, said last resonator having an axially positioned tubular member slidably engaging said rod-like electrode, and a third resonator surrounding the envelope between the input resonator and the output resonator, and providing a common wall with said output resonator, and a lip extending outwardly from said common wall engaged by the wall of the output resonator and having a sliding fit therewith, the common wall being electrically connected to said ring-like electrode whereby the output resonator may be tuned.

10. An electron discharge device having an elongated envelope and containing at one end a cathode for supplying a stream of electrons, and a pair of collector electrodes at the other end of said envelope, said collector electrodes comprising a ring electrode transverse to the longitudinal axis of said envelope, and a rod-like electrode extending axially of the envelope and positioned coaxially of said ring electrode, a pair of tubular electrodes positioned between the cathode and collector electrodes, the tubular electrode adjacent the cathode having a rod-like element extending within and coaxially of the other tubular electrode, said tubular electrodes and said ring-like electrodes being provided with radially directed conductors extending through the wall of the tube envelope, an input resonator closely

surrounding said tube envelope and having a gap registering with the gap between said tubular electrodes and electrically contacting the radially directed conductors of said tubular electrodes, and an output tank circuit connected to said collector electrodes.

11. An electron discharge device having an elongated envelope and containing at one end a cathode for supplying a stream of electrons, and a pair of collector electrodes at the other end of said envelope, said collector electrodes comprising a ring electrode transverse to the longitudinal axis of said envelope, and a rod-like electrode extending axially of the envelope and positioned coaxially of said ring electrode, a pair of tubular electrodes positioned between the cathode and collector electrodes, the tubular electrode adjacent the cathode having a rod-like element extending within and coaxially of the other tubular electrode, a resonator connected between said tubular electrodes, a resonator connected between the ring electrode and the rod-like electrode, and a resonator connected between the ring electrode and one of said tubular electrodes.

12. An electron discharge device having a cathode for supplying a stream of electrons and a plurality of collectors for receiving said electrons, electrode means for velocity modulating said stream of electrons including a pair of electrodes surrounding the path of said stream and spaced axially providing a gap surrounding said electron path between the cathode and collectors, and conducting means carried by one of said pair of electrodes extending axially within the other of said pair of electrodes.

13. An electron discharge device having a cathode for supplying a stream of electrons and a plurality of collectors for receiving said electrons, electrode means for velocity modulating said stream of electrons including a pair of tubular electrodes surrounding the path of said stream and spaced axially providing a gap surrounding said electron path between the cathode and collectors, and means carried by one of said tubular electrodes extending axially within the other tubular electrode, and a resonator connected between said pair of tubular electrodes, and a Lecher wire system connected between said collectors and a shielding compartment surrounding said collectors and Lecher wire system.

14. An electron discharge device having a cathode for supplying a stream of electrons, and a collector electrode means for receiving said electrons, means for modulating said electron stream and including a resonator having a gap surrounding the path of said electron stream between the cathode and collector electrode means, and a rod-like element electrically connected to said resonator on one side of said gap and extending axially within the resonator on the other side of said gap.

15. An electron discharge device having an elongated envelope containing at one end a cathode for supplying a stream of electrons, and a pair of collector elements at the other end of said envelope, a pair of electrodes positioned between the cathode and collector elements and spaced axially providing a gap, a rod element carried by one of said pair of electrodes and positioned coaxially within the other of said pair of electrodes, a resonator surrounding said envelope and having a gap registering with the gap between said pair of electrodes within said envelope.

16. An electron discharge device having a cathode for supplying a stream of electrons, and a plurality of concentric collector means for receiving said electrons, means intermediate said cathode and said collector means for subjecting the electrons to alternating electrical fields radially transverse to the stream of electrons for alternately directing electrons outwardly from the axial path of the electrons, and inwardly of the axial path of said electrons, whereby said electrons will be directed to one or the other of said collector means, said intermediate means comprising a tubular member through which said stream of electrons are to be directed, and a rod-like electrode member extending axially of and within said tubular member, said rod-like electrode and said tubular member being adapted to receive an alternating voltage therebetween.

17. An electron discharge device having a cathode for supplying a stream of electrons, and a plurality of concentric collector means for receiving said electrons, electrode means intermediate said cathode and said collector means and including concentric electrode elements for subjecting the electrons to alternating electrical fields radially transverse to the stream of electrons for alternately directing electrons outwardly from the axial path of the electrons, and inwardly of the axial path of said electrons, whereby said electrons will be directed to one or the other of said collector means.

18. An electron discharge device having a cathode for supplying a stream of electrons and an output electrode system for receiving said electrons, said output electrode system including a resonator provided with a central aperture and an axially positioned member, the end of which registers with said aperture, and electrode means positioned between the cathode and output electrode system, and comprising a pair of tubular conductors spaced axially providing a gap surrounding the path of the electron stream, one of said tubular conductors being provided with a rod-like extension positioned coaxially of and within the other tubular conductor, and a tank circuit connected between said tubular conductors.

19. An electron discharge device having a cathode for supplying a stream of electrons, and a collector electrode means for receiving said electrons, a pair of tubular electrodes positioned between the cathode and the collector electrode means and spaced axially providing a gap surrounding the path of the electron stream, a resonator connected between said tubular electrodes, and a shielding compartment surrounding said collector electrode means and slidably engaging said resonator, and conducting means carried by said sliding compartment and having an adjustable electrical connection with the collector electrode means.

20. An electron discharge device having a cathode for supplying a stream of electrons and a pair of output electrodes toward which said electrons are to be directed, one of said electrodes including a ring-like member and the other of said electrodes comprising a rod-like member coaxial with said ring-like member, a resonator surrounding the path of the electron stream between the cathode and output electrodes and having a gap surrounding the path of the electron stream, and a rod-like element connected to said resonator on one side of said gap and extending within and coaxially of said resonator on the other side of said gap, and a res-

onator connected between said output electrodes and comprising a wall transverse to the path of the electron stream and connected to said ring-like member, and having a lip extending from said wall, and a cup-shaped member, the open end of which slidably engages said lip and having a coaxial tubular conducting element slidably and electrically engaged with said rod-like member whereby said last resonator may be tuned.

21. An electron discharge device having an envelope containing at one end a cathode surrounded by a control electrode having a foraminous surface extending transversely of the envelope and provided with a collar surrounding the cathode and closely adjacent the wall of the envelope, collector electrode means positioned at the other end of said envelope, a pair of tubular electrodes positioned between the control electrode and collector electrode means and spaced axially providing a gap surrounding the discharge path between the cathode and collector electrode means, and a resonator surrounding the envelope and provided with a gap registering with the gap between the tubular electrodes, the inner portion of said resonator closely surrounding said envelope whereby capacity coupling is provided between said resonator and the collar of said control electrode and said tubular electrodes.

22. An electron discharge device having an envelope containing at one end a cathode surrounded by a control electrode having a foraminous surface extending transversely of the envelope and provided with a collar surrounding the cathode and closely adjacent the wall of the envelope, collector electrodes positioned at the other end of said envelope, a pair of tubular electrodes positioned between the control electrode and collector electrodes and spaced axially providing a gap surrounding the discharge path between the cathode and collector electrodes, and a resonator surrounding the envelope and provided with a gap registering with the gap between the tubular electrodes, the inner portion of said resonator closely surrounding said envelope whereby capacity coupling is provided between said resonator and the collar of said control electrode and said tubular electrodes for bypassing radio frequency currents, and a shielding compartment surrounding the end of the envelope containing the collector electrodes, and containing a pair of parallel conducting elements, one of which is connected to one of the collectors and the other of which is connected to the other collector.

23. An electron discharge device having an envelope containing at one end a cathode sur-

rounded by a control electrode having a foraminous surface extending transversely of the envelope and provided with a collar surrounding the cathode and closely adjacent the wall of the envelope, collector electrodes positioned at the other end of said envelope, a pair of tubular electrodes positioned between the control electrode and collector electrodes and spaced axially providing a gap surrounding the discharge path between the cathode and collector electrodes, and a resonator surrounding the envelope and provided with a gap registering with the gap between the tubular electrodes, the inner portion of said resonator closely surrounding said envelope whereby capacity coupling is provided between said resonator and the collar of said control electrode and said tubular electrodes for bypassing radio frequency currents, one of said collector electrodes being a transverse ring-like element having a radial lead extending through the wall of the envelope and the other of said collector electrodes being a rod-like element coaxial with said ring-like element and extending through the wall of said envelope, a shielding compartment surrounding the end of the envelope containing the collector electrodes and having a pair of conductors slidably and electrically engaged with said collector electrodes and providing therewith a tunable Lecher wire system.

24. An electron discharge device having a cathode for supplying a stream of electrons and a pair of output electrodes toward which said electrons are to be directed, a resonator surrounding the path of the electron stream between the cathode and output electrodes and having a gap surrounding the path of the electron stream, one of said pair of output electrodes having a radial lead terminating in a tubular member and the other of said pair of output electrodes having a longitudinal lead, a Lecher wire system including parallel conductors having telescoping relationship with said tubular member and said longitudinal lead.

25. An electron discharge device having a cathode for supplying a stream of electrons, a grid electrode adjacent said cathode and a pair of electrodes toward which said stream of electrons is to be directed, one of said pair of output electrodes having a radial lead terminating in a tubular member and the other of said pair of output electrodes having a longitudinal lead, a Lecher wire system including parallel conductors having telescoping relationship with said tubular member and said longitudinal lead, and a shield surrounding said parallel conductors.

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