

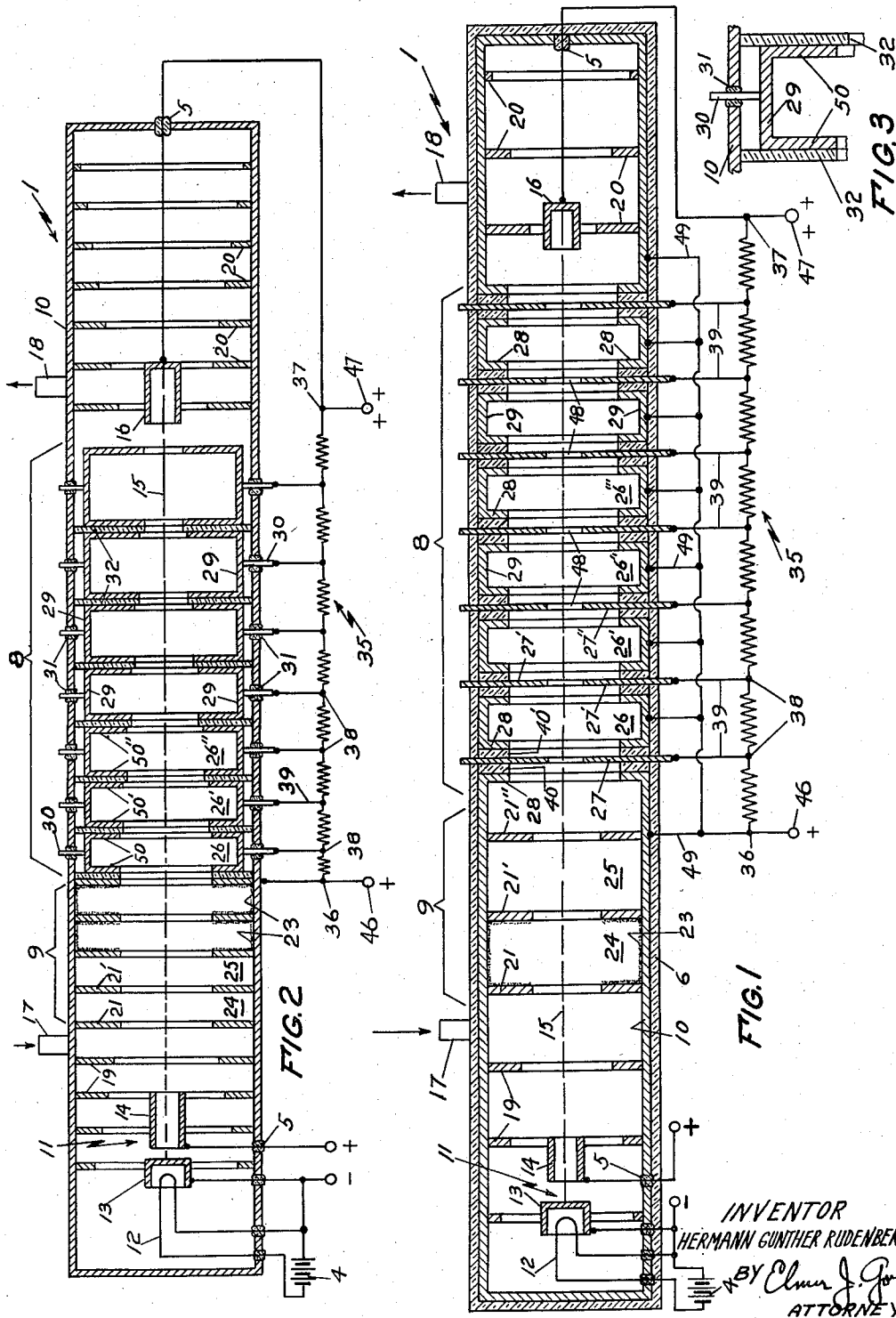
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TRAVELING WAVE TUBES

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TRAVELING WAVE TUBES

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This invention relates to an electron discharge device of the traveling wave tube type and, more particularly, relates to a device for achieving synchronism between the electromagnetic field wave and the space charge wave in a linear traveling wave tube.

The traveling wave tube is an evacuated electron-discharge device which operates by virtue of the interaction between the electric field of an electromagnetic wave and the space charge wave of an electron beam, both of which are traveling along the tube in the same direction at substantially the same velocity. The interaction between the electron beam and the electric field is such that the traveling wave increases in amplitude with distance; in other words, the traveling wave tube is an amplifying device.

In order to obtain an electromagnetic wave velocity substantially equal to (and preferably a little slower than) the velocity of the electron beam, the axial movement of the electromagnetic wave is retarded along the length of the tube.

The traveling wave tube of the subject invention utilizes a slow wave propagating structure. This may take the form of an evacuated wave guide containing a plurality of spaced disks or irises arranged normal to the wall of said wave guide and having centrally located apertures through which an electron beam may pass. Alternatively, the traveling wave tube may be in the form of an evacuated electron-discharge device containing a plurality of cavities positioned end-to-end with each cavity being bounded by two spaced iris portions arranged normal to the longitudinal axis of the tube through which the electron beam may pass.

At one end of the wave guide a conventional electron gun is mounted and at the other end of said wave guide a collecting electrode. High frequency electrical signal energy is fed into the wave guide at or near the end at which the electron gun is positioned. This energy is transferred along the wave guide and is taken from the opposite end of said guide by appropriate coupling means.

The radio frequency wave traveling along the wave guide is characterized by portions of varying potential. At a given instant of time, successive cavities or irises, as the case may be, are at different potentials, provided the cavities or irises are spaced properly for the frequency of the input R.F. energy.

As is well known in the art, electrons, in passing through a field in the direction of high to low potential, are retarded. This retardation of the electrons results in the latter giving up energy to the high frequency field. If the axial velocity of the electromagnetic field wave and the velocity of the electrons are equal, the electrons in the proper phase relation will always be traveling through a retarding field as they traverse the plurality of irises or cavities, as the case may be. The energy abstracted from the retarded electrons is transferred to the adjacent R.F. field and recovered at the collector end of the wave guide by suitable output coupling means. Since the energy transferred to the R.F. field is due to the slowing down of the electrons of the electron beam, the space charge

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wave does not normally remain in synchronism with the electromagnetic field wave throughout the length of the tube. In order that this synchronism may be retained in the region where considerable energy is abstracted from the space charge wave and transferred to the electromagnetic field wave, thereby obtaining maximum power amplification or efficiency from the tube, the space charge waves are in addition accelerated in the regions where they are retarded by the abstraction of high frequency energy.

This may be accomplished, for example, by charging successive irises (or cavities) to higher and higher D.C. potentials by means of a potentiometer connected across a source of direct current energy and having a plurality of taps to which the various individual irises (or cavities) are connected.

In the drawings:

Fig. 1 is a schematic illustration of a first embodiment of a traveling wave tube according to the invention;

Fig. 2 is a schematic illustration of a second embodiment of a traveling wave tube according to the invention; and

Fig. 3 is a detail view showing a portion of the tube structure of the traveling wave tube of Fig. 2.

Referring to Fig. 1, traveling wave tube 1 comprises a wave guide 10 closed at both ends and surrounded by an evacuated glass envelope 6. An electron gun 11 comprising a heater 12 energized by a battery or other source 4, a cathode 13 and an accelerating electrode 14 is mounted at one end of the wave guide. Electrode 14, which is connected to a positive voltage, is adapted to focus the electrons emitted from cathode 13 into an axial beam indicated by dotted line 15. As is usual in the traveling wave tube art, an axial magnetic field may be employed to aid in focusing the electron beam. A collector electrode 16, positioned at the opposite end of the wave guide, is connected to a source of voltage positive with respect to cathode 13. The elements of electron gun 11 and collector electrode 16 are connected externally of tube 1 through glass beads 5 in the wall of wave guide 10.

A source of high frequency energy is fed into the input end of wave guide 10 through an input wave guide 17 positioned in the proper energy-coupling relationship with wave guide 10. This high frequency energy after traversing the length of the tube is recovered by a similar output wave guide 18 positioned at the collector end of the tube, as shown in Fig. 1.

A series of successive irises 19 whose openings vary with their distance from the cathode end of the tube serve as the conventional impedance-matching means for effective coupling of energy into the input end of guide 10; similar irises 20 of progressively varying openings are located at the output end of guide 10 for output impedance matching. Located between the inputs to guide 10 and the main portion 8 of tube 10 is a series of irises 21, 21' etc., which serve as a bunching section 9 of the tube. The outer diameter of disks or irises 19, 20 and 21 is substantially equal to the inner diameter of wave guide 10 and said irises are adapted to be held in contact with the guide 10.

As the high frequency energy travels down the tube, a sinusoidally-varying potential is produced at various points along said tube. This high frequency field may be such that the instantaneous potentials at successive irises 21, 21', etc., will be out of phase. If electrons pass through the cavity 24 formed by two adjacent irises whose instantaneous polarities are plus and minus, respectively, in the direction of electron flow, the electrons will be acted on by the retarding field between said irises; electrons reaching the iris 21 at an earlier time will be retarded in reaching iris 21', but electrons leav-

ing the cathode at a later time arrive after a reversal of the field and so are accelerated after they pass through iris 21. In this way, the later-emitted but faster-moving electrons overtake the slower electrons of the beam which had preceded them in time, and a bunching of electrons may thereby be achieved. By the time the electrons moved into the adjacent cavity 25, the polarity of the sinusoidally-varying field has reversed and the electrons again encounter a retarding or accelerating field so that further bunching may be obtained.

By employing a series of said iris-walled cavities, excellent bunching of electrons in the electron beam is accomplished. Because of this bunching section of the tube, the energy extracted during traversals of the individual sections of the main portions of the tube is maximized, since there are fewer random movements of electrons in the beam which otherwise would provide cancelling out effects.

An attenuating coating 23, for example of aquadag graphite, placed on some or all of the irises 21 of the bunching section 9, serves as an attenuating means which is useful in preventing interaction between the input and output.

The bunched electrons now enter the first cavity resonator 26 of the main portion 8 of tube 1. Portion 8 includes a plurality of spaced irises 27, 27', etc., arranged normal to the wall of wave guide 10 and having centrally located apertures 48 through which electron beam 15 may pass. Section 8 of wave guide 10 is made up of a plurality of individual cavities 26, 26', etc., including flanged portions 28 and wall portions 29. The flanged portions 28 are separated from irises 27, 27', etc. by a pair of dielectric spacers 40, 40' mounted on both sides of the corresponding iris.

The potential distribution on the irises 27, 27' etc. in section 8 is such that the irises bounding a given cavity are at different potentials at any given instant of time; for example, irises 27 and 27' bounding the first cavity 26 encountered by the bunched electrons are at a given instant of time at positive and negative potentials, respectively, relative to one another. The electron bunch moving through this retarding field in cavity 26 is slowed down and these retarded electrons deliver their energy to the R.F. field which is in close proximity to said electron beam. If the electron bunch were not slowed down by the retarding field in cavities 26, 26', etc., the electron bunch would always be encountering a strong retarding field at each cavity of section 8 and maximum amplification could be obtained. However, a desired amount of amplification in the tube can be obtained only as a result of the transfer of energy from the electron bunches to the R.F. field. In order to be able to abstract the maximum energy from said tube, it is necessary that the velocity of propagation of the electrons down the tube to the collector should be substantially equal to the axial velocity of propagation of the electromagnetic field wave down the iris-loaded guide.

In order to retain synchronism between the electromagnetic field wave and the space charge wave in the output portion of the tube where energy is abstracted from the space charge wave and transferred to the electromagnetic field wave, an auxiliary accelerating field must be provided in the region 8 of the tube to offset the retardation of the space charge wave as energy is abstracted therefrom. The accelerating section comprises a potentiometer 35, whose ends 36 and 37 are connected, respectively, to the negative and positive terminals 46 and 47 of a direct current source of energy, such as a battery.

Potentiometer 35 contains a plurality of taps 38 to which the corresponding irises of section 8 are connected by leads 39, as shown in Fig. 1. Since the irises of section 8 are connected to the potentiometer, they

must be insulated from the walls of wave guide 10 for D.C. This is accomplished by means of a pair of dielectric disks 40, 40' etc., made of a material such as glass, mica or porcelain, which separate the corresponding irises 27, 27', etc. from the flanged portions 28 of wave guide 10. Each pair of dielectric disks 40, 40' together with guide flanged portions 28 and the corresponding iris 27 forms a pair of series-connected capacitors which permit the axial propagation of the R.F. electromagnetic wave down wave guide 10. In order to prevent the accumulation of charges on the walls of guide 10 (including the walls of cavities 26, 26', etc.), the wall portions 29 of cavities 26, 26' etc., and the ends of guide 10 are connected to terminal 46 of the direct current source by means of leads 49.

The position of the tap 38 along potentiometer 35 depends upon the R.F. voltage required at each of the irises 27. The direct current voltage distribution is preferably such that the increase in field strength from iris to iris resulting from the voltage derived from potentiometer 30 is substantially equal to the decrease in field strength from iris to iris due to the R.F. electromagnetic field.

A second embodiment of the invention is shown in Figs. 2 and 3, in which elements corresponding to those of Fig. 1 are designated by like reference numerals. The traveling wave tube 1 of Fig. 2 comprises an evacuated wave guide 10 containing a plurality of apertured cavities 26, each of which is distinguished from the other by an appropriate prime. For example, the first cavity or the cavity adjacent bunching section 9 is indicated as 26; the following resonator by 26', etc. Each cavity comprises a pair of spaced iris portions 50 and a wall portion 29 transverse to and interconnecting said iris portions. Cavities 26 are insulatedly supported at intervals along the wall of the tube by a series of rods or disks 30 which are sealed in glass beads 31 fused to the wall of wave guide 10. Such glass-to-metal seals are conventional and need not be described in detail. The iris portions of adjacent cavities 26 are insulated from one another for direct current voltages by means of dielectric spacers 32 made of material such as mica or glass. These spacers have low impedance to R.F. voltages, thereby permitting the axial transmission of the high frequency waves along the tube. Spacers 32, like irises 19, 20 and 21 are adapted to fit snugly against the walls of wave guide 10. The aforesaid rods 30 are connected to taps 38 on potentiometer 35 by leads 39. An enlarged view of a portion of the accelerating section of the traveling wave tube of Fig. 2 is shown in Fig. 3.

The function of the accelerating potentiometer 35 of Fig. 2, like that of Fig. 1, is to supply an accelerating field to offset the retarding force on the electrons resulting from the extraction of energy from the tube.

For optimum efficiency it is desirable to change the impedance of the cavity resonators to the R.F. electromagnetic wave along the length of the tube structure so as to operate at constant R.F. voltage or field and increasing current, otherwise some of the energy may be reflected backwards or else operation at constant R.F. voltage is not attained.

The power of the traveling wave amplifier increases linearly with distance, being proportional to the number of resonators. The power is given by

$$P_{r,t} = k \frac{V_{r,t}}{Z}$$

where $V_{r,t}$ is the voltage across each cavity.

If the R.F. voltage at each cavity is to be kept constant, the impedance Z must be decreased from one cavity to the next as the output end of the tube is approached.

The impedance may be varied by changing the spacing between iris portions 50, 50' etc. of cavities 26 and the diameter of the openings in said iris portions or both. As shown in Fig. 2, the spacing between adjacent iris

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portions '50, 50' etc. is successively increased. In order to maintain the phase velocity through each of the cavities constant, it is then necessary to decrease the size of the openings in the iris portions, as shown in Fig. 2.

It is, of course, possible to operate satisfactorily, albeit at reduced efficiency, with all of the individual cavities 26 of equal size. For example, the cavities may all be of the same size as that of initial cavity 26 of section 8 of tube 10 shown in Fig. 2.

What is claimed is:

1. A traveling wave tube comprising an electron gun positioned at one end of said tube for producing an electron beam, a collector electrode at the opposite end of said tube, said electron gun including means for directing said electron beam axially toward said collector electrode, a wave guide transmission path for high frequency waves having input and output energy coupling means, said transmission path being coaxially positioned relative to said electron beam and in energy coupling relationship therewith, said transmission path including means for extracting energy from said electron beam by retarding said beam, said wave guide containing a plurality of spaced cavities bounded by irises and by electrically conductive portions transverse to said irises, said cavities being insulated from each other by dielectric spacers attached to said wave guide, said cavities being insulated for direct currents from the walls of said wave guide and from each other, means external to said transmission path for producing an accelerating electrical field in the region of extraction of energy from said electron beam, the intensity of which field increases as a function of the distance from said one end of said tube, and means for connecting each of said cavities to separate portions of said field producing means.

2. A traveling wave tube as recited in claim 1 in which said cavities are of equal size and wherein adjacent cavities are in contact.

3. A traveling wave tube comprising an electron gun positioned at one end of said tube for producing an electron beam, a collector electrode at the opposite end of said tube, said electron gun including means for directing said electron beam axially toward said collector electrode, a wave guide transmission path for high frequency waves coaxially positioned relative to said electron beam and in energy-coupling relationship therewith, said transmission path including means for extracting energy from said electron beam by retarding said beam, said wave guide containing a plurality of spaced iris-walled cavities insulated for direct currents from the walls of said wave guide and from each other, the size of adjacent cavities being successively increased with distance from said one end of said tube so that the high frequency voltage and phase velocity at each of said cavities is maintained substantially constant, means external to said transmission path for producing an accelerating electrical field in the region of extraction of energy from said electron beam, the intensity of which field increases as a function of the distance from said one end of said tube, and means for connecting each of said cavities to separate portions of said field-producing means.

4. A traveling wave tube comprising an electron gun positioned at one end of said tube for producing an electron beam, a collector electrode at the opposite end of said tube, said electron gun including means for directing said electron beam axially toward said collector electrode, a wave guide transmission path for high frequency waves coaxially positioned relative to said electron beam and in energy-coupling relationship therewith, said transmission path including means for extracting energy from said electron beam by retarding said beam, said wave guide containing a plurality of spaced iris-walled cavities insulated for direct currents from the walls of said wave guide and from each other, and the size of the apertures in said irises being progressively decreased with distance from said one end of said tube so that the high frequency

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voltage and phase velocity at each of said cavities is maintained substantially constant, means external to said transmission path for producing an accelerating electrical field in the region of extraction of energy from said electron beam, the intensity of which field increases as a function of the distance from said one end of said tube, and means for connecting each of said cavities to separate portions of said field-producing means.

5. A traveling wave tube comprising a periodic slow wave transmission network structure for transmitting electromagnetic wave energy, said network structure being constructed to produce in a path adjacent thereto radio-frequency fields of the electromagnetic wave energy being transmitted, said network structure including a plurality of apertured spaced elements, a source of electrons disposed adjacent one end of said network structure, means for directing a beam of electrons adjacent said path for interaction with said fields of wave energy whereby energy may be extracted from said electron beam over an appreciable region of said path, means external to said network structure for producing an accelerating electric field in the region of extraction of energy from said electron beam to compensate for the retardation of said electron beam accompanying energy extraction from said beam, said accelerating field-producing means including means for supplying progressively increasing positive potentials to said elements as the distance from said one end of the tube increases, the size of said apertures in said elements being progressively increased in said region of energy extraction in the direction of said beam.

6. A traveling wave tube comprising a periodic slow wave transmission network structure for transmitting electromagnetic wave energy, said network structure being constructed to produce in a path adjacent thereto radio-frequency fields of the wave energy being transmitted, said network structure including a plurality of spaced apertured elements, a source of electrons disposed adjacent one end of said network structure, means for directing a beam of electrons adjacent said path through said apertures in said elements for interaction with said fields of wave energy whereby energy may be extracted from said electron beam over an appreciable region of said path, means external to said network structure for producing an accelerating electric field in the region of extraction of energy from said electron beam to compensate for the retardation of said electron beam accompanying energy extraction, said accelerating field-producing means including means for supplying progressively increasing positive potentials to said elements as the distance from said one end of said tube increases, the size of said apertures in said elements being progressively altered in said region of energy extraction.

7. A traveling wave tube comprising a periodic slow wave transmission network structure for transmitting electromagnetic wave energy, said network structure being constructed to produce in a path adjacent thereto radio-frequency fields of the wave energy being transmitted, said network structure including a plurality of spaced apertured elements, a source of electrons disposed adjacent one end of said network structure, means for directing a beam of electrons adjacent said path through said apertures in said elements for interaction with said fields of wave energy whereby energy may be extracted from said electron beam over an appreciable region of said path, means external to said network structure for producing an accelerating electric field in the region of extraction of energy from said electron beam to compensate for the retardation of said electron beam accompanying energy extraction, said accelerating field-producing means including means for supplying progressively increasing positive potentials to said elements as the distance from said one end of said tube increases, the spacing between adjacent elements and the size of said apertures being progressively altered in said region

of energy extraction, said alteration of said spacing and said aperture size being in the opposite sense.

8. A traveling wave tube comprising an electron gun positioned at one end of said tube for producing an electron beam, a collector electrode at the opposite end of said tube, said electron gun including means for directing said electron beam axially toward said collector electrode, a wave guide transmission path for high frequency waves coaxially positioned relative to said electron beam and in energy coupling relationship therewith, said transmission path including means for extracting energy from said electron beam by retarding said beam, said wave guide containing a plurality of spaced apertured irises insulated for direct currents from the walls of said wave guide and from each other, the spacing between adjacent irises being successively increased and the size of the apertures in said irises being progressively decreased with distance from said one end of said tube so that the high frequency voltage and phase velocity along the length of said tube is maintained substantially constant, means external to said transmission path for producing an accelerating electrical field in the region of extraction of energy from said electron beam, the intensity of which field increases as a function of the distance from said one end of said tube, and means for connecting each of said insulated irises to separate portions of said field producing means.

9. A traveling wave tube comprising an electron gun positioned at one end of said tube for producing an electron beam, a collector electrode at the opposite end of said tube, said electron gun including means for directing said electron beam axially toward said collector electrode, a wave guide transmission path for high frequency waves coaxially positioned relative to said elec-

tron beam and in energy-coupling relationship therewith, said transmission path including means for extracting energy from said electron beam by retarding said beam, said wave guide containing a plurality of spaced cavities bounded in part by a pair of spaced irises and insulated for direct currents from the walls of said wave guide and from each other, the size of the apertures in said irises being progressively decreased and the spacing between adjacent irises being progressively increased with distance from said one end of said tube so that the high frequency voltage and phase velocity at each of said cavities is maintained substantially constant, means external to said transmission path for producing an accelerating electrical field in the region of extraction of energy from said electron beam, the intensity of which field increases as a function of the distance from said one end of said tube, and means for connecting each of said cavities to separate portions of said field producing means.

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