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ELECTRON BEAM TRAVELING-WAVE TUBE

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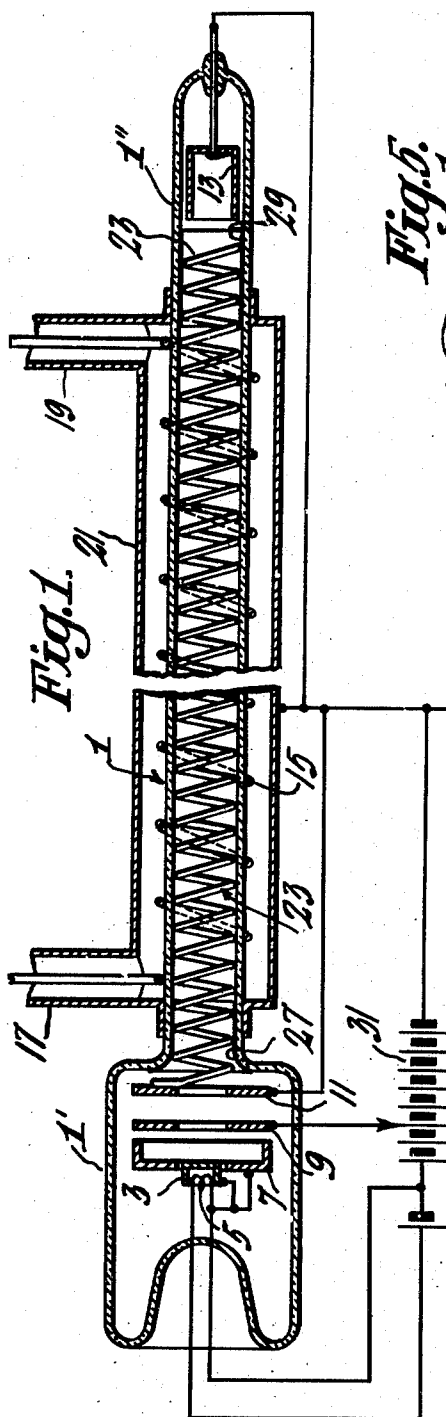


Fig. 5.



Fig. 6.

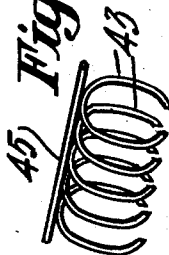


Fig. 8.

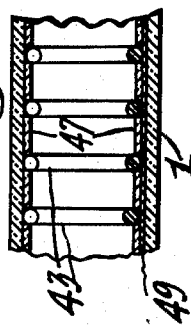


Fig. 7.

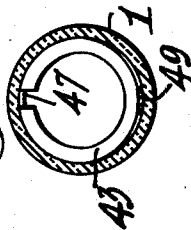


Fig. 3.

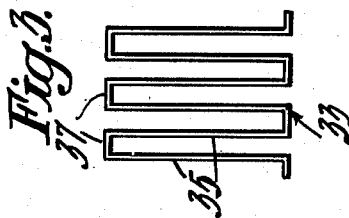
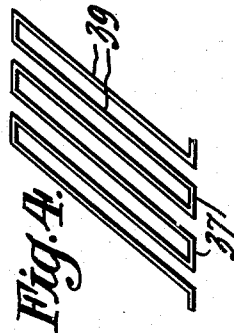
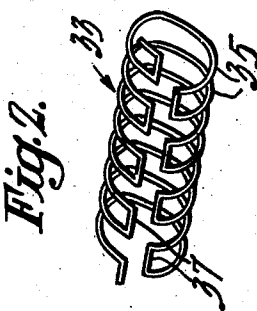


Fig. 2.



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ELECTRON BEAM TRAVELING-WAVE TUBE

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18 Claims. (Cl. 315—3.5)

This invention relates to electron beam tubes of the traveling wave type, primarily adapted for use as amplifiers at very high frequencies.

In a conventional traveling wave tube, an electromagnetic signal wave is coupled to one end of a delay line in the form of an elongated metal helix enclosed within an elongated evacuated envelope. The helix has such diameter and pitch that the axial velocity of a wave traveling along the turns of the helix is a small fraction, say one-tenth, of the velocity of light. An electron beam is projected along the helix in energy-transfer relation therewith, either inside or outside, at a velocity approximately equal to said axial wave velocity. Under such conditions, the electron beam and the traveling wave interact to cause the amplitude of the wave to increase exponentially, and hence, produce amplification of the signal. The amplified signal is utilized by suitable circuit means coupled to the output end of the helix. Instead of a metal helix, the wave-guiding means of the tube may be a baffle-loaded waveguide, folded waveguide, baffle-loaded coaxial line, waveguide partly filled with dielectric, or other structure capable of reducing the axial velocity of the wave therealong to practical electron velocities. Hence, such a traveling wave tube consists essentially of two basic structures: (1) a wave-guiding structure; and (2) a beam forming structure.

It has heretofore been customary in designing and constructing traveling wave tubes to locate both of these two basic structures within the tube envelope. As a result, the wave or phase velocity of the tube is fixed by the dimensions of the particular wave-guiding structure used. It is sometimes desirable to be able to alter the electrical characteristics of a particular tube after manufacture. This can be achieved by use of circuit elements which are located external to the vacuum envelope, and which can be replaced by different circuit elements without disturbing the vacuum. This result has been realized in certain other types of electron tubes having short interaction gaps, e. g. in klystrons, but has not heretofore been successfully accomplished in elongated-beam, multiple-interaction tubes, such as traveling wave tubes. The disadvantage of positioning the helix, or other circuit element, of a traveling wave tube outside the non-conducting glass envelope is the instability of the wall potential therealong, and therefore, of the beam velocity. This wall potential is caused by electrons of the long electron beam being collected by the wall of the envelope and thus building up an electric charge thereon.

The principal object of the invention is, therefore, to provide an improved traveling wave tube having interchangeable parts.

More specifically, the object is to provide a stable, "cartridge" traveling wave tube having easily-replaceable circuit elements located outside the tube envelope.

In accordance with the present invention, the interacting helix or other delay line of a traveling wave tube is located on the outside of the envelope wall, to make it easily replaceable, and a non-interacting, direct-current

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shield, substantially transparent to high frequency fields, is interposed between the electron beam and the envelope wall to stabilize the envelope wall potential. This shield may be in the form of a metal helix having dimensions determining an axial phase velocity at high frequencies different from that of the interacting helix and the velocity of the beam.

The advantages of the invention will be apparent from the following detailed description taken in connection with the annexed drawing, in which:

Fig. 1 is a longitudinal sectional view, partly schematic, of a traveling wave tube embodying the present invention;

Fig. 2 is a perspective view of a different type of shield which may be used in the tube of Fig. 1;

Fig. 3 is a plan view of the shield of Fig. 2 developed in a plane;

Fig. 4 is a plan view of a modification of the shield of Fig. 2 developed in a plane;

Figs. 5 and 6 are perspective views of two other modifications of the shield of Fig. 1; and

Figs. 7 and 8 are transverse and longitudinal sectional views, respectively, of a modification of the shield of Fig. 6.

Referring to the drawing, in which the same numerals indicate identical parts in the various views, Fig. 1 illustrates the present invention embodied in a helix type traveling wave tube. The tube comprises an elongated envelope 1, of glass or other dielectric material, having an enlarged gun receiving portion 1' at one end. Mounted in the portion 1' is an electron gun comprising a cathode 3, cathode heater 5, cathode shield 7, and accelerating electrodes 9 and 11, arranged to project an electron beam axially through the main portion 1'' of the envelope. The beam is collected by a collector electrode 13 in the other end of the envelope. The various electrodes are provided with suitable leads through the envelope as shown to permit the application of desired potentials thereto.

In accordance with the invention, the interacting wave-guiding structure or delay line is disposed on the outside of the envelope, instead of inside as in conventional traveling wave tubes. Therefore, a conductive spiral helix 15 is positioned outside the envelope portion 1'', as shown in Fig. 1. The helix 15 may be wound directly onto the envelope 1, or may be in the form of a pre-formed helix into which the envelope is inserted. As in conventional traveling wave tubes where the interacting helix is located within the tube envelope, the helix 15 extends along the major portion of the length of the tube. The helix 15 may be provided with any suitable input and output means. For example, the helix is shown as a continuation of the center conductors of an input coaxial line 17 and an output coaxial line 19, the outer conductors of which are connected to a tubular shield 21 which surrounds the helix 15 and a part of the envelope 1. With the helix 15 positioned outside the envelope 1, it is necessary to provide means for preventing instability due to the building of a variable charge on the inner wall of the envelope. Therefore, a substantially non-interacting, direct-current shield is interposed between the beam and the wall of the envelope along at least the portion of the envelope surrounded by the interacting helix 15. In Fig. 1, this shield is illustrated as an elongated conducting spiral helix 23 extending continuously along the inner wall of envelope 1 between the electron gun and the collector. The shield helix 23 acts as a collector for those stray electrons of the beam which would otherwise strike the envelope, and maintains the potential of the envelope wall constant.

The diameter and pitch of the interacting helix 15 are chosen so that signal waves travel along the helix at an optimum axial phase velocity at the normal operating frequency of the tube. In operation, the applied po-

tentials are adjusted to make the beam velocity substantially equal to the axial phase velocity of the helix 15. To prevent substantial interaction between the shield helix 23 and the signal wave along the interacting helix 15, the diameter and pitch of the shield helix 23 should be so chosen that the axial phase velocity of a wave along the shield helix is different from that of the interacting helix, at the operating frequency, so that the axial phase velocity along the shield helix will be different from the beam velocity during operation. For operation at a particular frequency the phase velocity along the shield helix may be either higher or lower than that along the interaction helix. However, since the tube may be operated over a wide range of frequencies, certain precautions are necessary to assure a minimum of interaction at all frequencies. The axial phase velocity of a wave along a helix in free space decreases with increase in frequency, being a predetermined fraction of the velocity of light at zero frequency, and asymptotically approaches a predetermined smaller minimum axial phase velocity, determined by the helix dimensions, at very high frequencies. Therefore, when the shield helix is designed to have a minimum axial phase velocity higher than that of the interacting helix, the two phase velocities at a particular operating frequency will always be different. It is sometimes desirable to use a shield helix whose minimum phase velocity is smaller than that of the interacting helix, in which case there is ordinarily at least one frequency for which the phase velocities of the two helices are equal. When the tube is operated at this frequency, oscillations will be excited in the shield helix. However, such oscillations cannot build up at any frequency if the shield helix is suitably terminated at both ends. In Fig. 1, the latter condition is illustrated, wherein the pitch of the shield helix 23 is much smaller than that of the interacting helix 15, and the diameter of helix 23 is almost as great as that of helix 15. Since the minimum phase velocity of helix 23 is smaller than that of helix 15, as shown, the shield helix 23 is terminated by resistive coating 27 and 29, of aquadag, for example, on the envelope wall at the ends of the helix and in contact with several turns thereof. The shield helix 23 may be wound in the same sense as the interaction helix 15, or the opposite sense.

The end of the shield helix 23 adjacent the electron gun is connected to the second accelerating electrode 11. In operation, the electrode 11, shield helix 23, shield 21 and collector 13 may be maintained at the same high positive potential relative to the cathode by a voltage source 31. The first accelerating electrode 9 is usually maintained at a potential intermediate the cathode and the second accelerating electrode 11.

External-helix traveling wave tubes which have been constructed in accordance with the present invention using a wire helix as the shield have given satisfactory results.

In order to provide a cartridge-type tube, the external helix 15, input line 17, shield 21 and output line 19 may be constructed as one unit detachable, by relative telescopic movement, from another unit made up of the envelope 1, electron gun, shield 23 and collector 13, so that either unit can be replaced by a similar unit having different structural details without disturbing the other unit.

Figs. 2-8, inclusive, illustrate several other forms of shield which should produce less alternating-current shielding than a helix.

Figs. 2 and 3 illustrate a modified shield conductor 33 which may be used in place of the shield helix 23 in the tube of Fig. 1. Conductor 33 consists of a series of spaced parallel ring portions 35 open at one side and joined by axially-extending connecting portions 37 as shown to form a continuous conductor. The ring portions 35 of Figs. 2 and 3 are disposed in planes perpendicular to the axis of the conductor 33.

Fig. 4 illustrates a development in a plane of a modification of the conductor 33 of Figs. 2 and 3 in which the ring portions 35 are replaced by spaced parallel helical portions 39.

In Fig. 5 the shield comprises a plurality of helical conductors of very long pitch interwound to form a shielding cage around the beam within the envelope 1.

In Fig. 6 the shield is made up of a series of spaced, parallel conducting rings 43 open at one side and connected together by an axially-extending connector 45.

Figs. 7 and 8 illustrate a modification of the shield of Fig. 6 wherein the open rings 43 are spaced from each other within the envelope 1 by means of dielectric spacer rings 47, and electrically connected together by a conducting strip in the form of a metallic coating 49 on the envelope wall.

From the foregoing description it is seen that the invention provides a stable traveling wave tube, useful as a wide-band amplifier, in which the circuit structure is disposed outside the tube envelope and a direct-current shield substantially transparent to alternating-current electric fields is provided inside the envelope and around the beam to prevent the accumulation of charge on the inner envelope wall. Although the invention has been specifically applied to a traveling wave tube of the helix type, it will be understood that it is also applicable to traveling wave tubes having other types of wave-guiding means as hereinbefore described.

What is claimed is:

1. An electron tube including a delay line adapted to transmit an electromagnetic wave therealong at a minimum axial phase velocity substantially less than the velocity of light, means for projecting an electron beam along a beam path extending adjacent to said delay line, dielectric wall means interposed between said beam path and said delay line, and direct-current shield means interposed between said dielectric wall means and said beam path, said shield means being substantially transparent to alternating-current electric fields.

2. An electron tube of the traveling wave type including elongated hollow wave-guiding means adapted to transmit an electromagnetic wave therealong at a minimum axial phase velocity substantially less than the velocity of light, means for projecting an electron beam along a beam path extending longitudinally through said wave-guiding means, dielectric wall means interposed between said beam path and said wave-guiding means, and direct-current shield means interposed between said dielectric wall means and said beam path, said shield means being substantially transparent to alternating-current electric fields.

3. An electron tube according to claim 2, including means coupled to the end of said wave guiding means nearest said beam projecting means for exciting traveling waves along said wave guiding means in accordance with a signal to be amplified, and means coupled to the opposite end of said wave guiding means for deriving amplified signal energy therefrom.

4. An electron tube according to claim 2, wherein said shield means comprises an elongated conducting helix.

5. An electron tube according to claim 4, wherein said wave-guiding means is adapted to transmit an electromagnetic wave therealong at a minimum axial phase velocity substantially less than the velocity of light, and said shield helix is adapted to transmit an electromagnetic wave therealong at a minimum axial phase velocity larger than that of said wave-guiding means.

6. An electron tube according to claim 5, wherein the minimum axial phase velocity of said shield helix is smaller than the minimum axial phase velocity of said delay line, further including resistive means terminating both ends of said shield helix to prevent oscillations from building up therein at any frequency.

7. An electron tube of the traveling wave type in-

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cluding an elongated dielectric envelope, an outer elongated metal interacting helix surrounding the major portion of said envelope, said interacting helix being adapted to transmit an electromagnetic wave therealong at a minimum axial phase velocity substantially less than the velocity of light, an inner elongated metal non-interacting direct-current shield helix within said envelope and extending continuously along at least that portion of the length of said envelope surrounded by said interacting helix, and means within said envelope for projecting an electron beam longitudinally through said inner helix, said shield helix being substantially transparent to alternating-current electric fields

8. An electron tube according to claim 7, wherein the diameters and pitches of said outer and inner helices are chosen so that the minimum axial phase velocities of the two helices are different.

9. An electron tube according to claim 8, wherein the minimum axial phase velocity of said inner helix is larger than the minimum axial phase velocity of said outer helix.

10. An electron tube according to claim 8, wherein the minimum axial phase velocity of said inner helix is smaller than the minimum axial phase velocity of said outer helix, further including resistive means terminating both ends of said inner helix.

11. An electron tube according to claim 10, wherein said resistive means comprises a resistive coating on the inner wall of said envelope in contact with several turns of said inner helix at each end thereof.

12. An electron tube according to claim 2, wherein said shield means comprises a plurality of conducting helices interwound to form a cage around said beam path.

13. An electron tube according to claim 2, wherein said shield means comprises a plurality of spaced, parallel, conducting rings open on one side, and means electrically connecting said rings together.

14. An electron tube according to claim 2, wherein said shield means comprises a plurality of spaced parallel conducting rings open on one side, and a plurality of conductors each connecting the ends of adjacent rings to form a continuous conductor.

15. An electron tube according to claim 2, wherein said shield means comprises a plurality of spaced parallel helical conducting members, and a plurality of conductors each connecting the ends of adjacent helical members to form a continuous conductor.

16. An electron tube according to claim 2, wherein said shield means comprises a plurality of spaced parallel conducting rings open on one side, and an elongated conductor extending along and in electrical contact with all of said rings.

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17. A cartridge-type electron tube comprising: a first unit including an elongated dielectric envelope, means for producing an electron beam along a beam path within said envelope and extending longitudinally thereof, and elongated direct-current shield means, substantially transparent to alternating-current electric fields, interposed between said beam path and the inner wall of said envelope; and a second unit including an elongated hollow delay line surrounding said shield means and said envelope for interaction with said beam, said two units being detachable whereby either unit can be replaced by a similar unit having different structural details without disturbing the other unit.

18. A cartridge-type traveling wave electron tube comprising: a first unit including an elongated dielectric envelope, means for projecting an electron beam in said envelope along a beam path extending longitudinally of said envelope, and elongated direct-current shield means substantially transparent to alternating-current electric fields interposed between said beam path and the inner wall of said envelope for stabilizing the potential of said inner wall; and a second unit telescoped over said first unit and including an elongated hollow wave-guiding delay line surrounding said shield means and said envelope, means coupled to the end of said delay line nearest said beam projecting means for exciting traveling waves along said delay line in accordance with a signal to be amplified, and means coupled to the opposite end of said delay line for deriving amplified signal energy therefrom; said two units being detachable, whereby structural changes can be made in either unit without disturbing the other unit.

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