July 1, 1969 R. S. CERKO 3,453,491

COUPLED CAVITY TRAVELING-WAVE TUBE WITH IMPROVED VOLTAGE STABILITY AND GAIN VS. FREQUENCY CHARACTERISTIC

Filed Jan. 25, 1965 Sheet 1 of 4

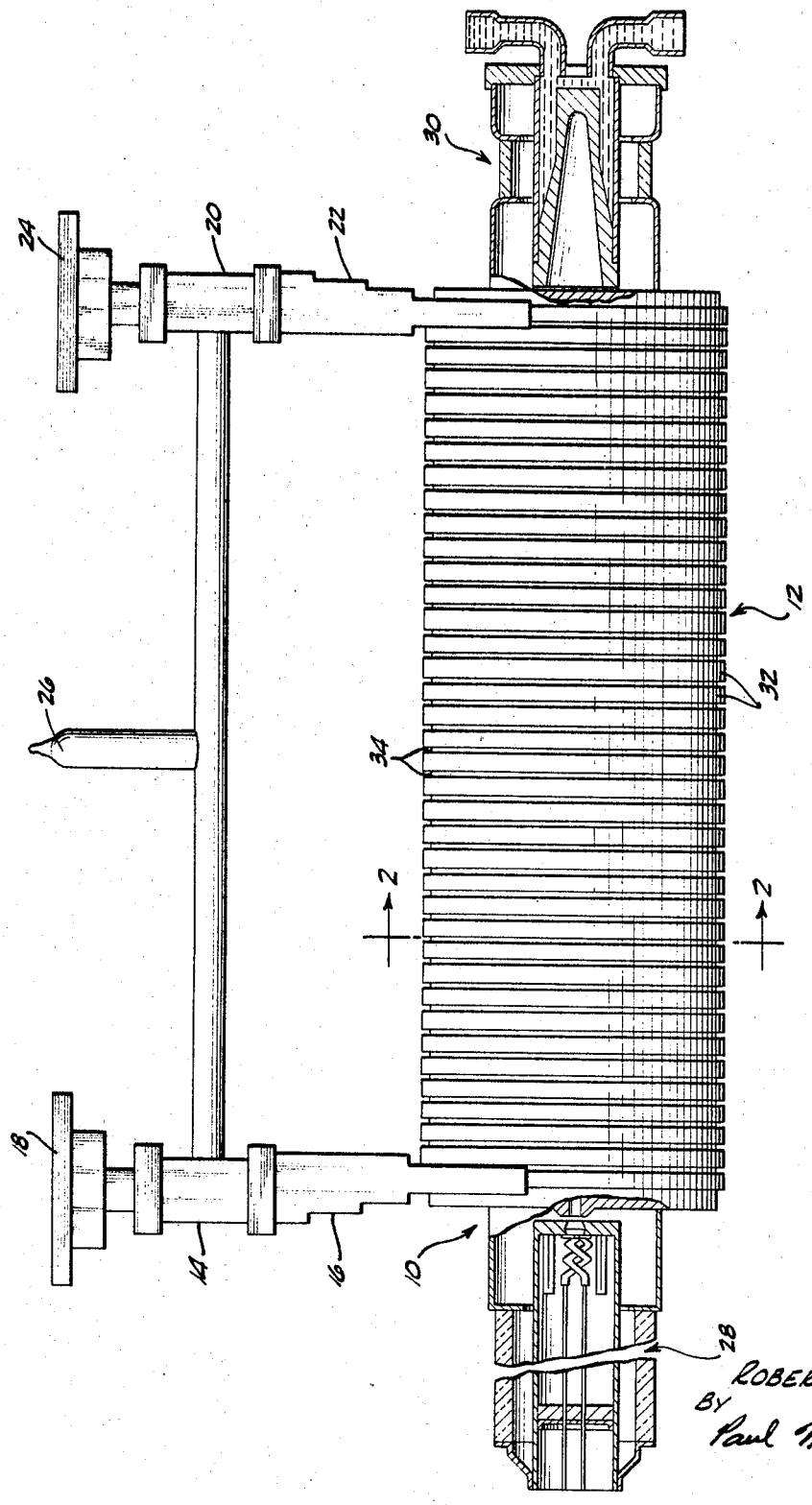


FIG. 1.

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COUPLED CAVITY TRAVELING-WAVE TUBE WITH IMPROVED VOLTAGE STABILITY AND GAIN VS. FREQUENCY CHARACTERISTIC

Filed Jan. 25, 1965 Sheet 2 of 4

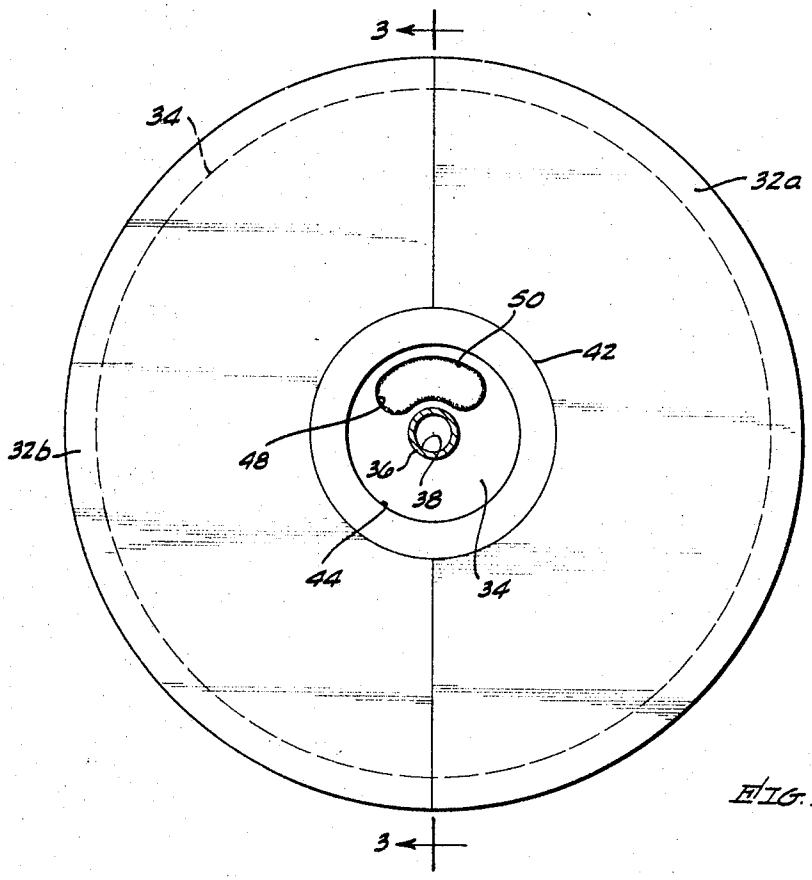


FIG. 2.

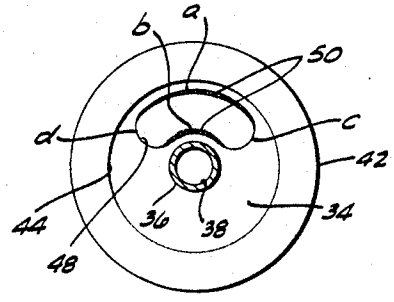


FIG. 4.

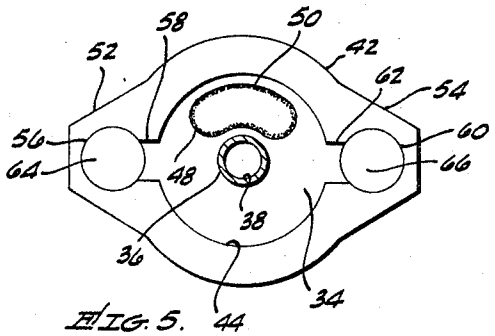


FIG. 5.

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COUPLED CAVITY TRAVELING-WAVE TUBE WITH IMPROVED VOLTAGE STABILITY AND GAIN VS. FREQUENCY CHARACTERISTIC

Filed Jan. 25, 1965 Sheet 3 of 4

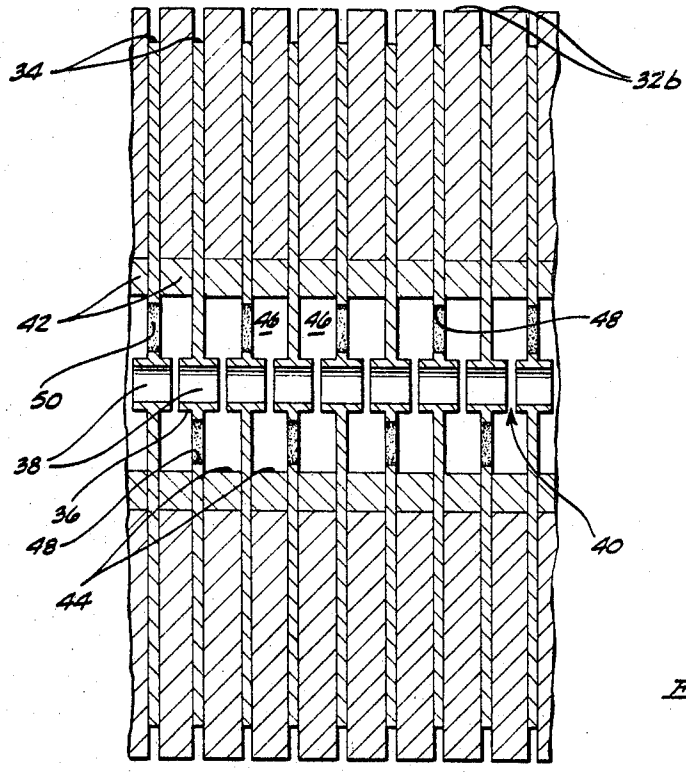


FIG. 3.

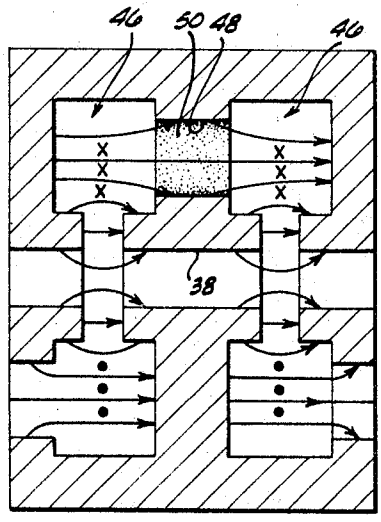


FIG. 6.

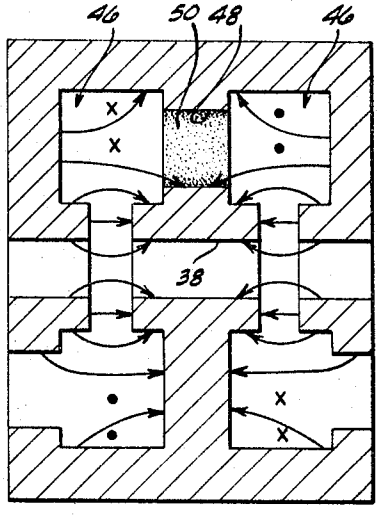


FIG. 7.

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COUPLED CAVITY TRAVELING-WAVE TUBE WITH IMPROVED VOLTAGE STABILITY AND GAIN VS. FREQUENCY CHARACTERISTIC

Filed Jan. 25, 1965 Sheet 4 of 4

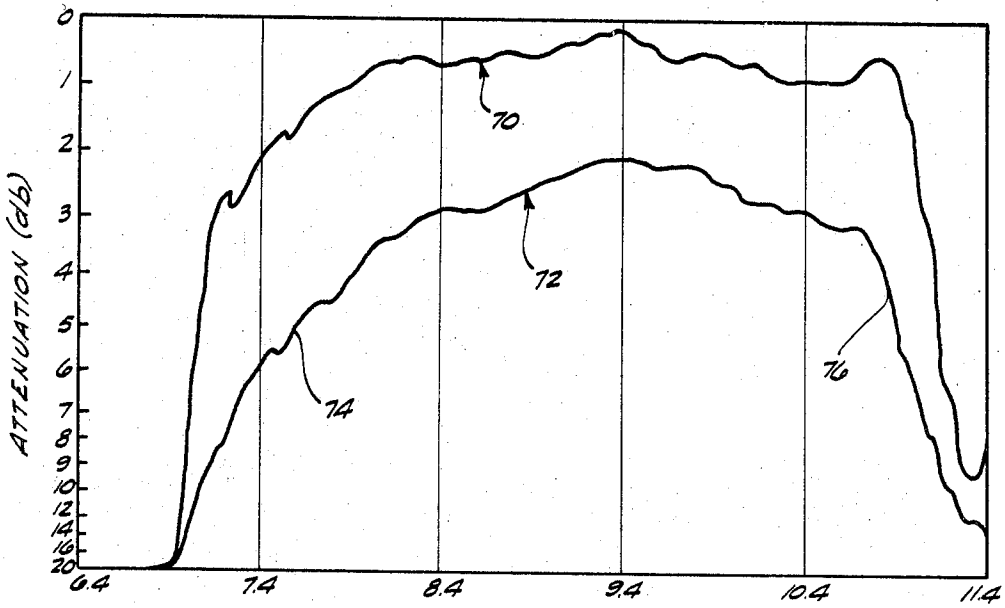


FIG. 8.

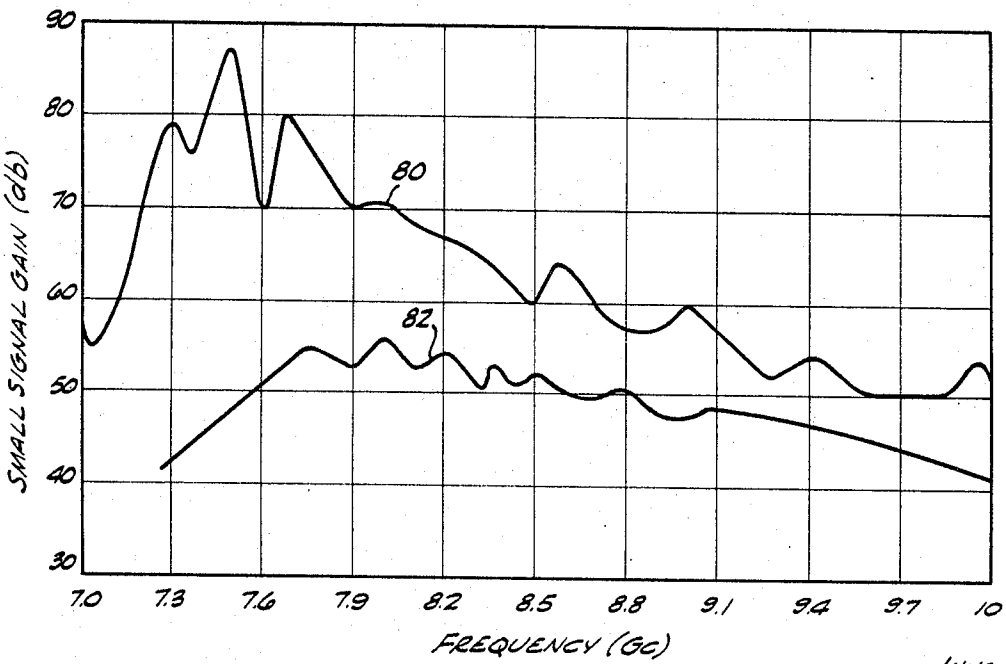


FIG. 9.

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United States Patent Office 3,453,491
Patented July 1, 1969

3,453,491

COUPLED CAVITY TRAVELING-WAVE TUBE WITH IMPROVED VOLTAGE STABILITY AND GAIN VS. FREQUENCY CHARACTERISTIC

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Filed Jan. 25, 1965, Ser. No. 427,704
Int. Cl. H01j 25/34
U.S. Cl. 315—3.5
20 Claims

This invention relates to traveling-wave tubes, and more particularly relates to a novel coupled cavity traveling-wave tube which provides a more uniform small signal gain as a function of frequency and which is capable of operating over a wider range of electron beam voltages without developing undesired oscillations.

In traveling-wave tubes a stream of electrons is caused to interact with a propagating electromagnetic wave in a manner which amplifies the electromagnetic energy. In order to achieve such interaction, the electromagnetic wave is propagated along a slow-wave circuit, such as a conductive helix wound about the path of the electron stream or a folded waveguide type of structure in which a waveguide is effectively wound back and forth across the path of the electrons. The slow-wave circuit provides a path of propagation for the electromagnetic wave which is considerably longer than the axial length of the circuit, and hence, the traveling-wave may be made to effectively propagate at nearly the velocity of the electron beam. The interactions between the electrons in the beam and the traveling-wave cause velocity modulations and bunching of the electrons in the beam. The net result may then be a transfer of energy from the electron beam to the wave traveling along the slow-wave circuit.

The present invention is concerned with traveling-wave tubes utilizing slow-wave circuits of the coupled cavity, or interconnected cell, type. In this type of slow-wave structure a series of interaction cells, or cavities, are disposed adjacent to each other sequentially along the axis of the tube. The electron beam passes through each interaction cell, and electromagnetic coupling is provided between each cell and the electron beam. Each interaction cell is also coupled to an adjacent cell by means of a coupling hole in the end wall defining the cell. Generally, the coupling holes between adjacent cells are alternately disposed on opposite sides of the axis of the tube, although various other arrangements for staggering the coupling holes are possible and have been employed. When the coupling holes are so arranged, a folded waveguide type of energy propagation results, with the traveling-wave energy tranversing the length of the tube by entering each interaction cell from one side, crossing the electron beam and then leaving the cell from the other side, thus traveling a sinuous, or serpentine, extending path.

For wide band operation of a traveling-wave tube, the phase velocity of the slow-wave circuit wave and the velocity of the electron beam should be essentially synchronized over as large a range of frequencies as possible. The velocity of the electron beam is determined by the voltage applied to the beam, and hence, as the beam voltage varies the degree of synchronism between the wave and beam velocities is altered. Since the interaction impedance is high and the circuit-to-transmisison line match is poor for frequencies at and in the vicinity of the edges of the tube passband, the wave and beam velocities may be sufficiently close to synchronism near the upper and lower cutoff frequencies of the tube for oscillations to start. Thus, a tendency toward band edge oscillations may limit the tube's voltage stability, i.e., the range of electron beam operating voltages throughout which the tube will not oscillate.

One technique which has been used to solve the band edge oscillation problem in a coupled cavity type of traveling-wave tube involves coupling to the slow-wave circuit interaction cells, specially designed cavities which are sharply resonant at a frequency in the vicinity of a cutoff frequency of the slow-wave circuit and providing lossy ceramic buttons in these special cavities in order to attenuate energy at the resonant frequency of the cavity. This technique is able to attenuate energy at those frequencies where the tube is most likely to oscillate without substantially affecting energy at frequencies throughout the remainder of the tube passband. However, the addition of the lossy resonant cavities alters the frequency-phase (ω–β) characteristic of the slow-wave circuit so that a minimum reflection coefficient is not provided throughout the entire slow-wave circuit passband. A low reflection coefficient is highly desirable in preventing large fluctuations in small signal gain as a function of frequency at the low frequency end of the tube passband.

In a further technique for preventing band edge oscillations and at the same time reducing small signal gain variations, at least one lossy ceramic transmission line in the form of a solid or coaxial rod is disposed proximate to and externally of the slow-wave circuit interaction cavities with its longitudinal axis parallel to the electron beam path. Coupling irises in the side walls of at least certain ones of the interaction cavities provide electromagnetic coupling between the slow-wave circuit and the lossy transmission line.

The lossy transmission approach introduces considerably less loss per interaction cavity than the lossy resonant cavity scheme, and as traveling-wave tubes are developed which operate at higher average power ratings and over wider bandwidths, it is necessary to employ band edge oscillation suppression techniques which minimize the small signal gain variations and maximize the voltage stability of tubes operating under these wider bandwidth and higher power requirements.

Accordingly, it is an object of the present invention to provide a high power, wide band, coupled cavity traveling-wave tube which affords a more uniform small signal gain as a function of frequency throughout the entire passband of the tube than has been accomplished in the past.

It is a further object of the present invention to provide a high power, wide band, coupled cavity traveling-wave tube which is capable of operating over a greater range of electron beam voltages without developing undesired oscillations than has heretofore been possible.

It is a still further object of the present invention to provide a coupled cavity traveling-wave tube having novel loss means for suppressing oscillations at the edges of the frequency passband of the tube, especially at the tube's lower cutoff frequency, and which loss means may be located entirely within the slow-wave structure so that when a periodic permanent magnet beam focusing scheme is utilized, a greater amount of magnetic material is available for focusing than with similarly dimensioned tubes having comparable prior art oscillation suppression schemes.

It is still another object of the present invention to provide novel loss means for suppressing oscillations at the lower cutoff frequency of a coupled cavity traveling-wave tube, and which loss means may, if desired, be used simultaneously with the aforementioned lossy resonant cavity scheme to achieve even greater control and shaping of the tube's gain vs. frequency characteristic over a very wide frequency range.

In accordance with the objects set forth above, a travel-

ing-wave tube according to the present invention includes means for providing a stream of electrons along a predetermined path and a slow-wave structure defining a plurality of interaction cavities disposed sequentially along and in electromagnetic interacting relationship with the electron stream for propagating electromagnetic wave energy in such manner that it can interact with the stream of electrons. The end walls separating adjacent ones of the interaction cavities define aligned apertures in their central regions to provide a passage for the electron stream and further define coupling holes in regions radially outwardly of their central regions for interconnecting adjacent interaction cavities so that the aforementioned electromagnetic wave propagation is possible. A coating of lossy material such as Kanthal is disposed on at least a portion of the surface of at least one of the coupling holes in order to afford the aforementioned improved voltage stability and gain vs. frequency characteristic.

Other and further objects, advantages and characteristic features of the present invention will become readily apparent from the following detailed description of preferred embodiments of the invention when considered in conjunction with the accompanying drawings in which:

FIG. 1 is an overall view partly in longitudinal section and partly broken away illustrating a traveling-wave tube according to the present invention;

FIG. 2 is a cross-sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a longitudinal sectional view taken along line 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view similar to FIG. 2 illustrating a portion of a traveling-wave tube according to another embodiment of the invention;

FIG. 5 is a cross-sectional view similar to FIG. 4 showing a portion of a traveling-wave tube in accordance with still another embodiment of the present invention;

FIG. 6 is a longitudinal sectional view illustrating electric and magnetic fields in the coupled cavity circuit of FIG. 3 in the vicinity of the upper cutoff frequency of the circuit;

FIG. 7 is a longitudinal sectional view illustrating electric and magnetic fields in the coupled cavity circuit of FIG. 3 near the lower cutoff frequency of the circuit;

FIG. 8 is a graph illustrating the attenuation as a function of frequency provided by the slow-wave circuit of a traveling-wave tube according to FIGS. 1–3, both with and without the lossy coating arrangement of the present invention; and

FIG. 9 is a graph showing the small signal gain as a function of frequency for a traveling-wave tube according to FIG. 1–3, both with and without the lossy coating arrangement of the present invention.

Referring to the drawings with more particularity, in FIG. 1 the reference numeral **10** designates generally a traveling-wave tube which includes an arrangement **12** of magnets, pole pieces and spacer elements which will be described in detail later. At this point it should suffice to state that the spacer elements and interior portions of the pole pieces function as a slow-wave structure, while the magnets and pole pieces constitute a periodic focusing device for the electron beam traversing the length of the slow-wave structure.

Coupled to the input end of the arrangement **12** is an input waveguide transducer **14** which includes an impedance step transformer **16**. A flange **18** is provided for coupling the assembled traveling-wave tube **10** to an external waveguide or other microwave transmission line (not shown). The construction of the flange **18** may include a microwave window (not shown) transparent to microwave energy but capable of maintaining a vacuum within the traveling-wave tube **10**. At the output end of the arrangement **12** an output transducer **20** is provided which is substantially similar to the input transducer **14** and which includes an impedance step transformer **22** and a coupling flange **24**, which elements are similar to the elements **16** and **18**, respectively, of the input transducer **14**. For vacuum pumping or out-gassing the traveling-wave tube **10** during manufacture, a double-ended pumping tube **26** is connected to both of the input and output waveguide transducers **14** and **20**.

An electron gun **28** is disposed at one end of the traveling-wave tube **10** which, although illustrated as the input end in FIG. 1, may alternatively be the output end if a backward wave device is desired. The electron gun **28** functions to project a stream of electrons along the axis of the tube **10** and may be of any conventional construction well known in the art. For details as to the construction of the gun **28** reference is made to Patent No. 2,985,791, entitled "Periodically Focused Severed Traveling-Wave Tube," issued May 23, 1961 to D. J. Bates et al. and assigned to the assignee of the present invention and to Patent No. 2,936,393, entitled "Low Noise Traveling-Wave Tube," issued May 10, 1960 to M. R. Currie et al. and assigned to the assignee of the present invention.

At the output end of the traveling-wave tube **10** there is provided a cooled collector structure **30** for collecting the electrons in the stream. The collector is conventional and may be of any form well known in the art. For details as to the construction of the collector, reference is made to the aforesaid Patent No. 2,985,791 and to Patent No. 2,860,277, entitled "Traveling-Wave Tube Collector Electrode," issued Nov. 11, 1958 to A. H. Iversen and assigned to the assignee of the present invention.

The construction of the slow-wave structure and magnetic focusing system for the traveling-wave tube **10** are illustrated in more detail in FIGS. 2 and 3. A plurality of essentially annular disk-shaped focusing magnets **32** are interposed between a plurality of ferromagnetic pole pieces **34**. As illustrated in FIG. 2, the magnets **32** may be diametrically split into two sections **32***a* and **32***b* for convenience during assembly of the tube. The ferromagnetic pole pieces **34** extend radially inwardly of the magnets **32** to approximately the perimeter of the region adapted to contain the axial electron stream. The individual pole pieces are constructed in such a manner that a short drift tube, or ferrule, **36** is provided at the inner extremity of each pole piece. The drift tube **36** is in the form of a cylindrical extension, or lip, protruding axially along the path of the electron stream from both surfaces of pole piece **34**, i.e., in both directions normal to the plane of the pole piece **34**. The drift tubes **36** are provided with central and axially aligned apertures **38** to provide a passage for the flow of the electron beam. Adjacent ones of the drift tubes **36** are separated by a gap **40** which functions as a magnetic gap to provide a focusing lens for the electron beam and also as an interaction gap in which energy exchange between the electron beam and traveling-wave energy traversing the slow-wave structure occurs.

Disposed radially within each of the magnets **32** is an annular slow-wave circuit spacer element **42** of an electrically conductive nonmagnetic material such as copper. Each spacer element **42** has an outer diameter essentially equal to the inner diameter of the magnets **32** and defines a central cylindrical aperture **44** to provide space for a microwave interaction cell, or cavity, **46** which is defined by the inner lateral surface of the spacer **42** and the walls of the two adjacent pole pieces **34** projecting inwardly of the spacer element **42**. The inner diameter of the spacer **42** determines the radial extent of the interaction cell **46**, while the axial length of the spacer **42** determines the axial length of the cell **46**.

For interconnecting adjacent interaction cavities **46** an off-center coupling hole **48** is provided through each of the pole pieces **34** to permit the transfer of electromagnetic wave energy from cell to cell. As is illustrated, the coupling holes **48** may be substantially kidney-shaped and may be alternately disposed 180° apart with respect to the drift tubes **36**. It should be pointed out, however, that the coupling holes **48** may be of other shapes and

may be staggered in various other arrangements, such as those disclosed in Patent No. 3,010,047, entitled "Traveling-Wave Tube," issued Nov. 21, 1961 to D. J. Bates and assigned to the assignee of the present invention. In any event, it will be apparent that the spacer elements **42** and the portions of the pole pieces **34** projecting inwardly of the spacers **42** not only form an envelope for the tube, but also constitute a slow-wave structure for propagating traveling-wave energy in a serpentine path along the axially traveling electron stream so as to support energy exchange between the electrons of the stream and the traveling-wave.

The axial length of the magnets **32**, hence that of the spacers **42**, is equal to the spacing between adjacent pole pieces **34**, and the radial extent of the magnets **32** is approximately equal to or, as shown, slightly greater than that of the pole pieces **34**. To provide focusing lenses in the gaps **40**, the magnets **32** are stacked with alternating polarity along the axis of the tube, thus causing a reversal of the magnetic field at each magnetic lens and thereby providing a periodic focusing device. It should be pointed out, however, that although the lengths of the spacers **42** may be substantially constant, they may also be varied slightly with respect to each other so that the effective axial length of the cavities **46** is varied as a function of distance along the tube to ensure that the desired interaction between the electron stream and the traveling waves will continue to a maximum degree even though the electrons are decelerated toward the collector end of the tube.

In accordance with the present invention, in order to eliminate band edge oscillations while decreasing small signal gain variations and improving the voltage stability in the aforedescribed traveling-wave tube, a coating **50** of a lossy material is disposed along the peripheral surfaces of the coupling holes **48**. Although it is preferred to use Kanthal as the lossy material, other lossy materials may be employed such as mixtures including various percentages of iron, chromium, aluminum, aluminum oxide, chromium oxide, and silicon carbide in a binder such as amyl acetate. The percentages of these constituent materials will vary depending upon the upon the amount of loss to be introduced and the desired the slow-wave structure.

In the embodiment shown in FIGS. 2 and 3 the lossy coating **50** extends around the entire peripheral surface of the coupling hole **48**; however, the lossy coating may cover only a portion of the coupling hole peripheral surface. Thus, as is illustrated in FIG. 4 the lossy coating **50** may be applied to the circumferentially extending (with respect to circles centered on the electron beam axis) portions *a* and *b* of the peripheral surface of the coupling hole **48** but not to the generally radially extending more sharply curved portions *c* and *d* of the coupling hole surface. It is also possible to locate the lossy coating **50** on only one of the surfaces *a* or *b* depending the amount of loss to be introduced and the desired shape for the gain vs. frequency characteristic. Moreover, the lossy coating **50** may be applied to either all of the coupling holes **48** or to only a selected one or ones of the coupling holes.

In order to achieve even greater shaping of the gain vs. frequency characteristic over a very wide frequency range, the coupling hole lossy coatings **50** may be used simultaneously with a lossy resonant cavity oscillation suppression arrangement, and an embodiment of the present invention utilizing such a combination is illustrated in FIG. 5. In this embodiment the spacer element **42** defines a pair of oppositely disposed ear portions **52** and **54** projecting outwardly from its central portion which defines the interaction cavity aperture **44**. A cylindrical cavity **56** is provided in the ear portion **52** and is coupled to the central aperture **44** in the spacer **42** by means of a coupling hole, or iris, **58**. Similarly, the ear portion **54** on the other side of the spacer **42** defines a cylindrical cavity **60** which is coupled to the central aperture **44** via a coupling iris **62**. The cavities **56** and **60** are designed to resonate in the TM_{010} mode at a frequency at which loss is to be introduced into the slow-wave circuit. Cylindrical button-like elements **64** and **66** of a mixture of ceramic and lossy materials, for example forsterite and silicon carbide, are disposed in the respective cavities **56** and **60** in order to provide the desired loss. When the arrangement of FIG. 5 is employed, the cavities **56** and **60** preferably should be designed to resonate at a frequency in the vicinity of the upper cutoff frequency of the slow-wave circuit so as to introduce the desired loss at the high frequency end of the slow-wave circuit passband, while the coating **50** affords the desired loss at the low frequency end of the passband.

As has been indicated above, the lossy coating arrangement of the present invention is more effective in introducing attenuation at the low frequency end of the slow-wave circuit passband than at the high frequency end. The reason for this may be better understood by making reference to FIGS. 6 and 7 which illustrate both the electric and magnetic fields in an axial plane through the center of a coupling hole **48** of a slow-wave circuit in accordance with FIGS. 2 and 3 at the upper and lower cutoff frequencies, respectively, of the slow-wave circuit. The electric field is designated by arrowed lines, while the magnetic field is designated by crosses and dots, the crosses indicating a field directed into the plane of the paper away from the reader and the dots designating a field directed out of the plane of the paper toward the reader. As may be observed from FIG. 6, in the vicinity of the upper cutoff frequency the electric field entering the coupling hole **48** at one end is essentially balanced out by the electric field leaving coupling hole **48** at the other end. Thus, essentially very little net current flows through the lossy coating **50** and a minimum amount of energy is dissipated in the coating **50**. On the other hand, as may be seen from FIG. 7, in the vicinity of the lower cutoff frequency the electric field enters the coupling hole **48** from both adjacent cavities **46**. This produces a substantial net current flow through the lossy coating **50**, thereby dissipating a sufficient amount of energy in the coating **50** to achieve the desired attenuation.

The attenuation as a function of frequency provided by the slow-wave structure of a traveling-wave tube constructed in accordance with FIGS. 1–3, both with and without the lossy coatings **50**, is illustrated in FIG. 8. In this figure the curve **70** depicts the attenuation with no lossy material located in the coupling holes **48**, while the curve **72** portrays the attenuation when the entire peripheral surfaces of the coupling holes **48** are covered with Kanthal. For a slow-wave circuit provided with lossy-coated coupling holes **48**, it may be observed that as the frequency is increased from the lower cutoff frequency of the slow-wave circuit at around 7.0 gc., the attenuation decreases gradually along the portion **74** of the curve **72**, essentially levels off, and then after a frequency of around 10.7 gc. is reached increases rapidly along the curve portion **76** until the upper cutoff frequency is reached in the vicinity of 11.2 gc.

The small signal gain as a function of frequency for a traveling-wave tube constructed in accordance with FIGS. 1–3, both with and without the lossy coatings **50** is illustrated in FIG. 9. In this figure the curve **80** illustrates the small signal gain for a traveling-wave tube without any lossy coating in the coupling holes **48**, while the curve **82** shows the small signal gain when Kanthal coatings **50** cover the peripheral surfaces of the coupling holes **48**. As may be seen from the curve **80**, when no lossy coatings **50** are employed substantial fluctuations in small signal gain occur at the low frequency end of the tube passband producing a variation of from around 55 db to around 87 db. Also, a gradual overall reduction in small signal gain occurs from around 87 db to around 50 db as the tube passband is traversed from slightly above the

lower cutoff frequency to the upper cutoff frequency of the tube. On the other hand, as is shown by the curve **82**, when the lossy coatings **50** are present in the coupling holes **48**, the wide excursions in small signal gain at the low frequency end of the tube passband are substantially eliminated, and in addition the overall decrease in small signal gain is reduced to around 14 db as the passband is traversed from slightly above the lower cutoff frequency to the upper cutoff frequency of the tube.

Moreover, whereas the electron beam voltage could be varied throughout a range of only around 800 volts without oscillations developing in a tube constructed without the lossy coatings **50**, when the Kanthal coatings **50** were applied to coupling holes **48** in accordance with the principles of the present invention, the electron beam voltage could be varied over a range of 3500 volts without the development of oscillations. Thus, it will be apparent that the coupled cavity traveling-wave tube of the present invention provides a much more uniform small signal gain as a function of frequency and is capable of operating over a substantially wider range of electron beam voltages without developing undesired oscillations.

Although the present invention has been shown and described with reference to particular embodiments, nevertheless, various changes and modifications obvious to a person skilled in the art to which the invention pertains are deemed to be within the spirit, scope and contemplation of the invention as set forth in the appended claims.

What is claimed is:

1. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means for propagating electromagnetic wave energy in such manner that it can interact with said stream of electrons, said slow-wave structure means defining a plurality of interaction cavities disposed sequentially along and in electromagnetic interacting relationship with said stream of electrons, the end walls separating adjacent ones of said cavities defining aligned apertures in their central regions to provide a passage for said stream of electrons and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities, and a coating of lossy material disposed on at least a portion of the surface of at least one of said coupling holes.

2. A traveling-wave tube according to claim **1** wherein said lossy material is Kanthal.

3. A traveling-wave tube according to claim **1** wherein said coating covers substantially the entire peripheral surface of said one of said coupling holes.

4. A traveling-wave tube according to claim **1** wherein said coating covers substantially the entire peripheral surface of each of said coupling holes.

5. A traveling-wave tube according to claim **1** wherein said coupling holes are substantially kidney-shaped and have a peripheral surface including first and second portions which extend substantially along the respective circumferences of circles centered on the axis of said predetermined path, and said coating is disposed substantially on said first and second portions only of said one of said coupling holes.

6. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, a plurality of axially aligned essentially annular electrically conductive spacer elements sequentially disposed along and encompassing said predetermined path, a plurality of electrically conductive plates each mounted between a pair of adjacent spacer elements to define in conjunction with said spacer elements a plurality of interaction cavities, said plates defining aligned apertures in their central regions to provide a passage for said stream of electrons and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities to provide a propagation path for electromagnetic wave energy such that interaction between said stream of electrons and said electromagnetic wave energy can occur, and a coating of lossy material disposed on at least a portion of the surface of at least one of said coupling holes.

7. A traveling-wave tube according to claim **6** wherein said lossy material is Kanthal.

8. A traveling-wave tube according to claim **6** wherein said coating covers substantially the entire peripheral surface of said one of said coupling holes.

9. A traveling-wave tube according to claim **6** wherein said coating covers substantially the entire peripheral surface of each of said coupling holes.

10. A traveling-wave tube according to claim **6** wherein said coupling holes are substantially kidney-shaped and have a peripheral surface including first and second portions which extend substantially along the respective circumferences of circles centered on the axis of said predetermined path, and said coating is disposed substantially on said first and second portions only of said one of said coupling holes.

11. A traveling-wave tube comprising: means for launching a stream of electrons along a predetermined path, a plurality of axially aligned essentially annular magnets, a plurality of ferromagnetic pole pieces interposed and abutting adjacent magnets, an essentially annular nonmagnetic spacer element having an outer diameter essentially equal to the inner diameter of said essentially annular magnets disposed within each of said magnets, said pole pieces projecting inwardly of said spacer elements to define in conjunction therewith a plurality of interaction cavities, said pole pieces defining aligned apertures in their central regions to provide a passage for said stream of electrons and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities to provide a propagation path for electromagnetic wave energy such that interaction between said stream of electrons and said electromagnetic wave energy can occur, and a coating of lossy material disposed on at least a portion of the surface of at least one of said coupling holes.

12. A traveling-wave tube according to claim **11** wherein said lossy material is Kanthal.

13. A traveling-wave tube according to claim **11** wherein said coating covers substantially the entire peripheral surface of said one of said coupling holes.

14. A traveling-wave tube according to claim **11** wherein said coating covers substantially the entire peripheral surface of each of said coupling holes.

15. A traveling-wave tube according to claim **11** wherein said coupling holes are substantially kidney-shaped and have a peripheral surface including first and second portions which extend substantially along the respective circumferences of circles centered on the axis of said predetermined path, and said coating is disposed substantially on said first and second portions only of said one of said coupling holes.

16. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, a plurality of axially aligned essentially annular electrically conductive spacer elements sequentially disposed along and encompassing said predetermined path, a plurality of electrically conductive plates each mounted between a pair of adjacent spacer elements to define in conjunction with said spacer elements a plurality of interaction cavities, said plates defining aligned apertures in their central regions to provide a passage for said stream of electrons and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities to provide a propagation path for electromagnetic wave energy within a predetermined frequency range having an upper cutoff frequency and a lower cutoff frequency such that interaction between said stream of electrons and said electromagnetic wave energy can occur, at least one of said spacer elements defining at least one outwardly extending ear portion, said ear por-

tion defining a cylindrical cavity coupled to the interaction cavity defined by said spacer element, said cylindrical cavity being resonant at said upper cutoff frequency, a lossy ceramic element disposed in said cylindrical cavity, and a coating of lossy material disposed on at least a portion of the surface of at least one of said coupling holes.

17. A traveling-wave tube according to claim **16** wherein said lossy material is Kanthal.

18. A traveling-wave tube according to claim **16** wherein said coating covers substantially the entire peripheral surface of said one of said coupling holes.

19. A traveling-wave tube according to claim **16** wherein said coating covers substantially the entire peripheral surface of each of said coupling holes.

20. A traveling-wave tube according to claim **16** wherein said coupling holes are substantially kidney-shaped and have a peripheral surface including first and second portions which extend substantially along the respective circumferences of circles centered on the axis of said predetermined path, and said coating is disposed substantially on said first and second portion only of said one of said coupling holes.

References Cited

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3,324,339 6/1967 Winslow et al.

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PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,453,491 Dated July 1, 1969

Inventor(s) R. S. Cerko

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 52, "tranversing" should be --traversing--.
Col. 5, line 43, delete "upon the";
delete "to be introduced and the";
after "desired" insert --and the material used to form--.
line 56, after "depending" insert --upon--.

SIGNED AND
SEALED
JUN 16 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, J
Commissioner of Patent