Nov. 21, 1967 A. LAVIK 3,354,346

TRAVELING-WAVE TUBE HAVING LOSS-FILLED, CAPACITIVELY-COUPLED CAVITIES COUPLED TO THE INTERACTION CELLS OF THE SLOW-WAVE STRUCTURE

Filed Oct. 23, 1964 3 Sheets-Sheet 1

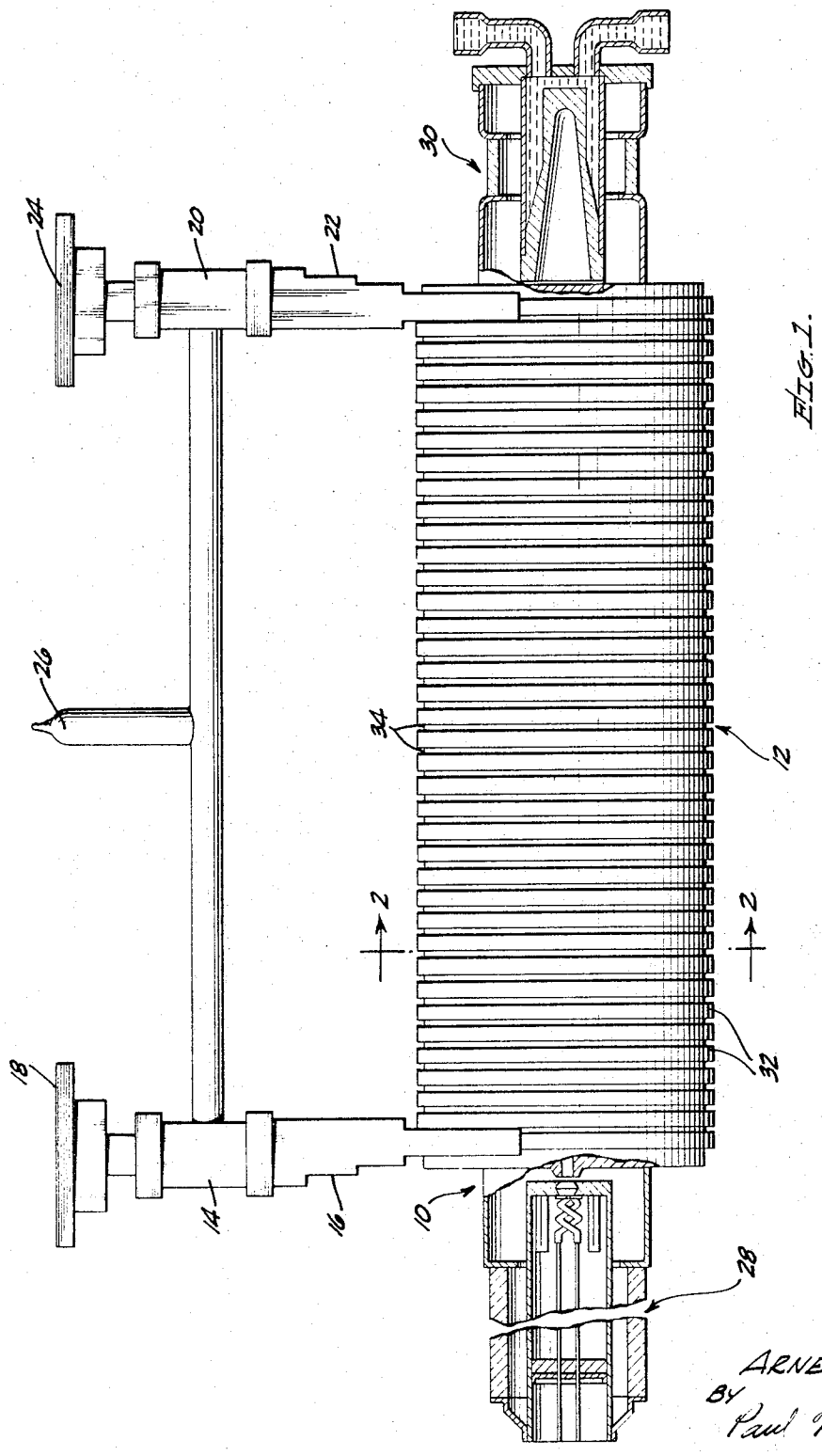


FIG. 1.

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Filed Oct. 23, 1964 3 Sheets-Sheet 2

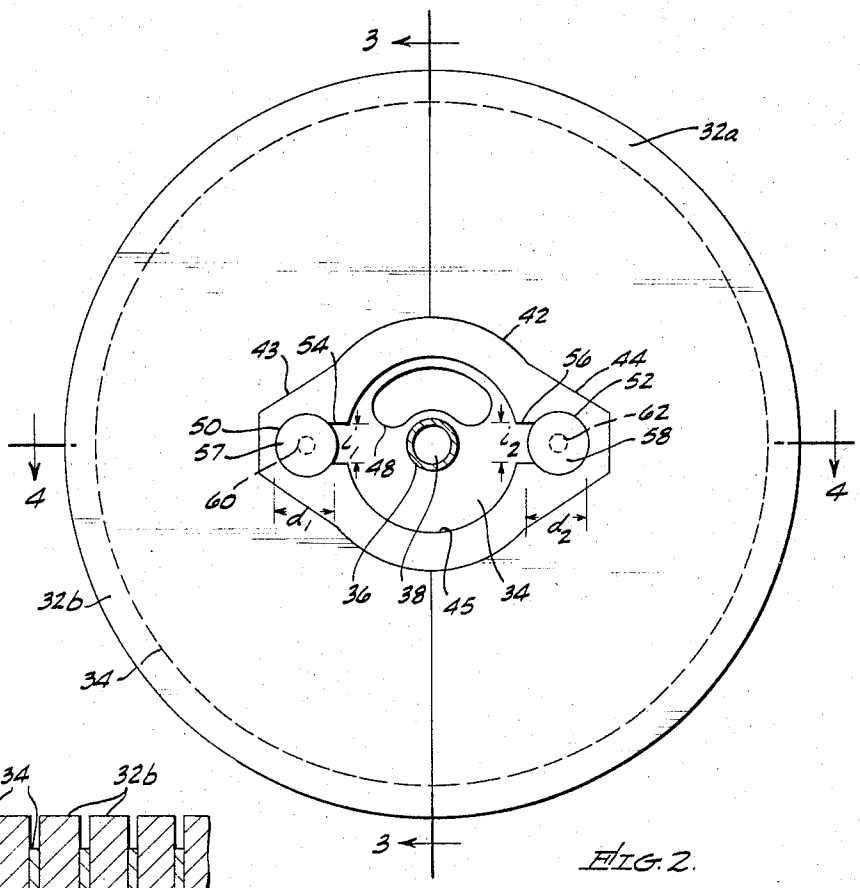


FIG. 2.

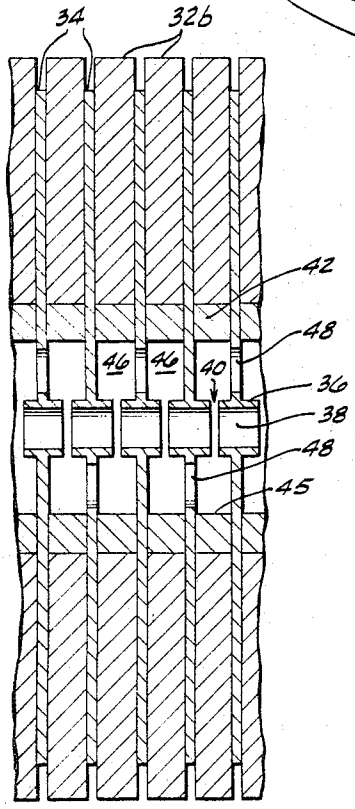


FIG. 3.

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Filed Oct. 23, 1964 3 Sheets-Sheet 3

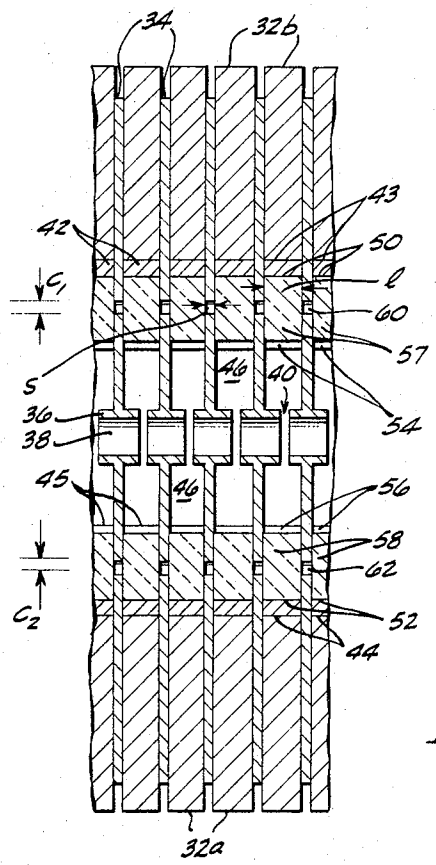


FIG. 4.

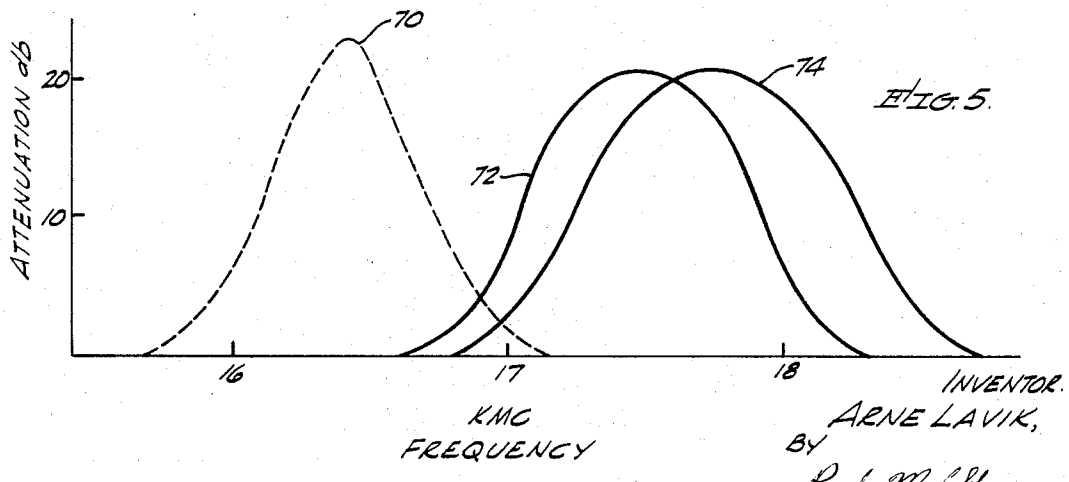


FIG. 5.

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United States Patent Office 3,354,346 Patented Nov. 21, 1967

3,354,346

TRAVELING-WAVE TUBE HAVING LOSS-FILLED, CAPACITIVELY-COUPLED CAVITIES COUPLED TO THE INTERACTION CELLS OF THE SLOW-WAVE STRUCTURE

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Filed Oct. 23, 1964, Ser. No. 406,120
6 Claims. (Cl. 315—3.5)

This invention relates generally to microwave devices, and more particularly relates to traveling-wave tubes having novel and improved means for substantially eliminating oscillations at desired frequencies, such as those at the edges of the frequency passband of the tube.

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 structure, 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 structure provides a path of propagation for the electromagnetic wave which is considerably longer than the axial length of the structure, and hence, the traveling-wave may be made to effectively propagate at nearly the velocity of the electron stream. The interactions between the electrons in the stream and the traveling-wave cause velocity modulations and bunching of the electrons in the stream. The net result may then be a transfer of energy from the electron beam to the wave traveling along the slow-wave structure.

The present invention is primarily, although not necessarily, concerned with traveling-wave tubes utilizing slow-wave structures 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 stream passes through each interaction cell, and electromagnetic coupling is provided between each cell and the electron stream. Each interaction cell is also coupled to an adjacent cell by means of a coupling hole at 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 traversing the length of the tube by entering each interaction cell from one side, crossing the electron stream and then leaving the cell from the other side, thus traveling a sinuous, or serpentine, extended path.

One of the problems encountered in traveling-wave tubes of the coupled cavity variety, and especially high power tubes of this type, is a tendency for the tube to oscillate at frequencies near the edges of the tube passband. This problem arises from the fact that for wide band operation 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; hence, these velocities are also close to synchronism near the upper and lower cutoff frequencies of the tube. Since the interaction impedance is high and the circuit-to-transmission line match is poor at and in the vicinity of the cutoff frequencies, the loop gain for the tube, or even for a section of the tube, may be sufficiently large for oscillations to start.

One technique which has been used to solve this oscillation problem involves coupling to the slow-wave structure interaction cells specially designed cavities which are sharply resonant at a frequency in the vicinity of a cutoff frequency of the slow-wave structure and providing lossy ceramic buttons in these special cavities in order to attenuate energy at the resonant frequency of the cavity. Each lossy resonant cavity has a relatively high Q and thus provides a large amount of loss over a narrow frequency band. In order to obtain a sufficiently wide bandwidth for the attenuation it has been the practice to tune respective loss cavities in a portion of the tube to slightly different frequencies throughout the desired attenuation frequency band. This tuning may be accomplished by changing the dimensions of either the lossy resonant cavities or the irises which coupled the loss cavities to the slow-wave circuit interaction cells, or both, by altering the loss button material, or by loading the loss cavities with conductive stubs of varying dimensions. It will be apparent that such a cavity tuning procedure requires considerable time and effort, thereby increasing the manufacturing time and complexity, and hence, the cost of the traveling-wave tube.

Accordingly, it is an object of the present invention to provide a high-power wide-bandwidth traveling-wave tube having means for preventing oscillations at the edges of the frequency passband of the tube, and which oscillation preventing means lends itself to the ready, rapid, efficient, and inexpensive manufacture of the traveling-wave tube.

It is a further object of the present invention to provide a traveling-wave tube of the type employing lossy resonant cavities for oscillation suppression and in which the amount of loss and the Q of the lossy cavities are more readily controllable than in the prior art.

It is a still further object of the present invention to provide a traveling-wave tube which employs lossy resonant cavities to attenuate energy at frequencies at the edges of the slow-wave circuit frequency passband, and which lossy resonant cavities provide more stable attenuation than in the prior art.

It is still another object of the present invention to provide a lossy resonant cavity oscillation suppression arrangement for a traveling-wave tube which affords a greater loss-bandwidth product than comparable prior art arrangements.

In accordance with the foregoing objects, the traveling-wave tube of the present invention includes means for providing a stream of electrons along a predetermined path and a slow-wave structure having a plurality of intercoupled interaction cells disposed sequentially along and about the electron stream path for propagating electromagnetic wave energy in such manner that it interacts with the stream of electrons. A plurality of cavities are sequentially disposed along a direction parallel to the electron stream path, with each cavity being electromagnetically coupled to one of the interaction cells and being resonant at a preselected frequency. Loss means is disposed in each of the cavities for attenuating electromagnetic wave energy at the resonant frequency of the cavity. Wall means separating each pair of adjacent resonant cavities define an aperture for providing capacitive coupling directly between the pair of resonant cavities in order to afford the improved loss vs. frequency characteristics of the present invention.

The foregoing, as well as other objects, advantages, and characteristic features of the present invention will become more readily apparent from the following detailed description of a preferred embodiment 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, of a traveling-wave tube constructed in accordance with 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 longitudinal sectional view taken along line 4—4 of FIG. 2; and

FIG. 5 is a series of graphs illustrating the attenuation as a function of frequency for traveling-wave tube lossy resonant attenuating devices according to both the prior art and 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. 2–4. A plurality of essentially annular disk-shaped focusing magnets **32** are interposed between a plurality of ferromagnetic pole pieces **34**. As is 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 a slow-wave circuit spacer element **42** of a conductive nonmagnetic material such as copper. Each spacer element **42** has an annular portion of an outer diameter essentially equal to the inner diameter of the magnets **32** and a pair of oppositely disposed ear portions **43** and **44** projecting outwardly from the annular portion. Each spacer element also defines a central cylindrical aperture **45** 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 tube.

In order to minimize any tendency for the traveling-wave tube to oscillate at frequencies near the edges of the slow-wave circuit passband, frequency selective attenuation is provided to substantially decrease the gain at these frequencies and, thereby, suppress the oscillations. This attenuation takes the form of lossy ceramic elements disposed in cavities which are coupled to the

slow-wave circuit interaction cells and which cavities are made resonant at the frequencies to be attenuated. Thus, as is shown in FIGS. 2 and 4, a slow-wave circuit spacer element **42** may define a pair of cylindrical cavities **50** and **52** which are respectively disposed in the projecting ear portions **43** and **44** of the spacer element **42**. The cavity **50** has a diameter "d_1" and is coupled to the central aperture **45** in the spacer **42** by means of a coupling hole, or iris, **54** of width "i_1." Similarly, the cavity **52** has a diameter "d_2" and is coupled to the spacer aperture **45** via a coupling iris **56** of width "i_2." The diameters "d_1" and "d_2" for the respective cavities **50** and **52** may either have the same or a different value, and similarly, the iris widths "i_1" and "i_2" may or may not be equal. As may be seen from FIG. 4, the cavities **50** and **52** have a length l equal to the thickness of the slow-wave circuit spacer element **42**. The cavities **50** and **52** are designed to resonate in the TM_{010} mode at a frequency at which loss is to be introduced into the circuit. Although the cavity resonant frequency is preferably at or near either the upper or lower cut-off frequency of the slow-wave circuit, it is understood that the resonant loss frequency may be any preselected frequency.

Cylindrical button-like elements **57** and **58** of a mixture of ceramic and lossy materials are disposed in the respective cavities **50** and **52** in order to provide the desired loss. A composition which may be used for the buttons **57** and **58** is a mixture of forsterite and silicon carbide, with the percentage of silicon carbide being essentially between 3% and 10%. Examples of other materials which could be used are silicon carbide and alumina, silicon carbide and talc, or other ceramic and lossy material combinations.

For the TM_{010} mode, the cavity resonant frequency is determined by the diameter of the cavity and the dielectric constant of the lossy material. However, since the normal TM_{010} cylindrical cavity mode is perturbed by the relatively large irises **54** and **56** which are designed to provide critical coupling into the respective cavities **50** and **52**, the cavity resonant frequency also becomes a function of the iris dimensions. Thus, the cavity diameter d, the iris width i, and the dielectric constant of the lossy material in the buttons **57** and **58** must be varied dependently to achieve the desired attenuation at the desired frequency. In addition, it should be pointed out that as the composition of the lossy ceramic mixture is changed the Q of the resonance will be affected, i.e., as the percentage of silicon carbide is increased the Q will decrease.

In prior art resonant loss arrangements the pole pieces **34** provide solid end walls for the resonant cavities **50** and **52**, and thus the only coupling with the cavities **50** and **52** is through the respective irises **54** and **56** to the slow-wave circuit interaction cells **46**. In such arrangements each lossy resonant cavity has a relatively high Q and hence provides a large amount of attenuation over a relatively narrow band of frequencies. Since this frequency band may be of insufficient width to afford the desired oscillation suppression, a stagger tuning principle has been employed. For example, different resonant loss cavities are tuned to slightly different frequencies near the slow-wave structure upper cutoff frequency so as to introduce loss in contiguous or even overlapping narrow frequency bands in the vicinity of the upper cutoff frequency, thereby forming a composite loss band of greater width than the individual loss bands provided by the respective resonant cavities.

In accordance with the present invention a widening of the resonant loss band is afforded without stagger-tuning the individual cavities and in a manner which insures a stable attenuation vs. frequency characteristic regardless of changes in environmental conditions such as temperature. These advantageous results are achieved by providing capacitive coupling directly between axially adjacent ones of the resonant loss cavities **50** or **52**. For this purpose cylindrical coupling apertures **60** of a diameter c_1 are provided in the pole pieces **34** between adjacent cavities **50** on one side of the slow-wave structure, and similar coupling apertures **62** having a diameter c_2 are provided in the pole pieces between adjacent cavities **52** on the other side of the slow-wave structure. The coupling apertures **60** are coaxially aligned with the cylindrical cavities **50**, while the apertures **62** are coaxially aligned with the cavities **52**. Preferably, the diameters c_1 and c_2 of the coupling holes **60** and **62**, respectively, vary from essentially between 0.2 and 0.7 of the diameters d_1 and d_2 of the resonant cavities **50** and **52**. The length of the coupling apertures **60** and **62**, which is equal to the thickness of the pole piece **34** defining the apertures, is denoted by s in FIG. 4. The diameters c_1 and c_2 for the respective coupling apertures **60** and **62** may or may not be equal.

The manner in which the resonant loss cavity capacitive coupling arrangement of the present invention affects the attenuation vs. frequency characteristics of the slow-wave structure is illustrated in FIG. 5. In this figure the dashed curve **70** depicts the attenuation as a function of frequency for a prior art scheme in which no capacitive coupling is provided between axially adjacent resonant loss cavities. In the exemplary arrangement from which data for the curve **70** was taken the diameters d_1 and d_2 of the resonant cavities **50** and **52** were both .150 inch, the coupling iris widths i_1 and i_2 were both .130 inch, the cavity length l was .096 inch, the pole piece thickness s was .040 inch, the coupling aperture diameters c_1 and c_2 were both zero, and the loss buttons **57** and **58** each contained 3½% silicon carbide and 96½% forsterite.

Attenuation vs. frequency characteristics for resonant loss arrangements in accordance with the present invention are illustrated by the solid curves **72** and **74** of FIG. 5. The curve **72** was made from a slow-wave circuit-resonant loss arrangement having parameters identical to those set forth above with respect to the curve **70**, except that cylindrical coupling apertures **60** and **62** were provided in the pole pieces **34** between adjacent resonant loss cavities **50** and **52**, respectively, the diameters c_1 and c_2 for the coupling apertures **60** and **62** each being .075 inch. The curve **74** was made from an arrangement identical to that from which the curve **72** was plotted, except with a coupling aperture diameter $c_1=c_2=.090$ inch.

From inspection of FIG. 5, it will be apparent that as the coupling aperture diameter increases the bandwidth of the attenuation band increases substantially, the center frequency of the attenuation band increases somewhat, and the amplitude of the maximum attenuation decreases very slightly. Thus, the loss-bandwidth product of the resonant loss arrangement of the present invention may be seen to be substantially greater than an arrangement of the prior art otherwise having the same parameters. It will also be apparent from FIG. 5 that both the amount of loss and the Q of the lossy resonant cavities may be controlled by varying the diameter of the capacitive coupling holes **60** and **62**, thereby affording a further and more workable way to control these parameters than in the prior art. Moreover, a sufficiently wide loss band may be introduced without the necessity for stagger-tuning the individual resonant loss cavities, thereby decreasing manufacturing time and complexity, and hence, reducing the cost of the traveling-wave tube. In addition, since the coupled lossy resonant cavity arrangement of the present invention eliminates the necessity for forming the desired wide loss band with a plurality of individual narrower loss bands, any possibility of the formation of gaps in the attenuation vs. frequency characteristic due to resonance shifting of an individual loss button as a function of temperature or other environmental changes is precluded, thereby affording more stable attenuation than in the prior art.

Although the present invention has been shown and described with reference to a particular enbodiment, 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 defining a plurality of intercoupled interaction cells disposed sequentially along and about said predetermined path for propagating electromagnetic wave energy in such manner that it interacts with said stream of electrons, means defining a plurality of cavities sequentially disposed along a direction parallel to said predetermined path, each of said cavities being electromagnetically coupled to one of said interaction cells and being resonant at a preselected frequency, means for providing capacitive coupling directly between adjacent ones of said cavities, and loss means disposed in each of said cavities for attenuating electromagnetic wave energy at the resonant frequency of the cavity.

2. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means defining a plurality of intercoupled interaction cells disposed sequentially along and about said predetermined path for propagating electromagnetic wave energy in such manner that it interacts with said stream of electrons, means defining a plurality of sequentially disposed cylindrical cavities aligned with one another along a direction parallel to said predetermined path, each of said cavities being electromagnetically coupled to one of said interaction cells and being resonant at a preselected frequency, said cavity defining means including electrically conductive wall means separating adjacent ones of said cavities, said wall means defining a cylindrical aperture coaxially aligned with said cylindrical cavities for providing electromagnetic coupling between said adjacent ones of said cavities, and loss means disposed in each of said cavities for attenuating electromegnatic wave energy at the resonant frequency of the cavity.

3. A traveling-wave tube according to claim 2 wherein said loss means comprises an element of a mixture of silicon carbide and a material selected from the group consisting of forsterite, alumina and talc, with the percentage of silicon carbide being essentially between 3% and 10%.

4. A traveling-wave tube according to claim 2 wherein each of said cavities is resonant in the TM_{010} mode.

5. 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 cells, said plates defining aligned apertures in their central regions to provide a passage for said electron stream and further defining coupling holes in regions readily outwardly of said central regions for interconnecting adjacent interaction cells whereby a propagation path is provided for an electromagnetic wave in a manner to provide interaction between said electron stream and said electromagnetic wave, at least certain successive ones of said spacer elements defining aligned cylindrical cavities coupled to the respective interaction cells defined by the spacer elements, each of said cavities being resonant at a preselected frequency, each of said plates which is interposed between a pair of successive cylindrical cavities defining a cylindrical aperture intercoupling said pair of cylindrical cavities, and loss means disposed in each of said cylindrical cavities for attenuating electromagnetic energy at the resonant frequency of the cavity.

6. 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 between and abutting adjacent magnets, a hollow essentially cylindrical 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 internally of said spacer elements to define therewith a plurality of interaction cells, said pole pieces defining aligned apertures in their central regions to provide a passage for said electron stream and further defining coupling holes in regions readily outwardly of said central regions for interconnecting adjacent cells whereby a propagation path is provided for an electromagnetic wave in a manner to provide interaction between said electron stream and said electromagnetic wave, at least certain successive ones of said spacer elements each defining at least one outwardly extending ear portion, at least certain successive ones of said ear portions defining aligned cylindrical cavities coupled to the respective interaction cells defined by the spacer elements, each of said cavities being resonant at a preselected frequency, each of said plates which is interposed between a pair of successive cylindrical cavities defining a cylindrical aperture coaxially aligned with and intercoupling said pair of cylindrical cavities, and loss means disposed in each of said cylindrical cavities for attenuating elecromagnetic energy at the resonant frequency of the cavity.

References Cited

UNITED STATES PATENTS

3,221,204 11/1965 Hant et al. ---------- 315—3.5

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