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CAVITY RESONATOR FOR KLYSTRON TUBE

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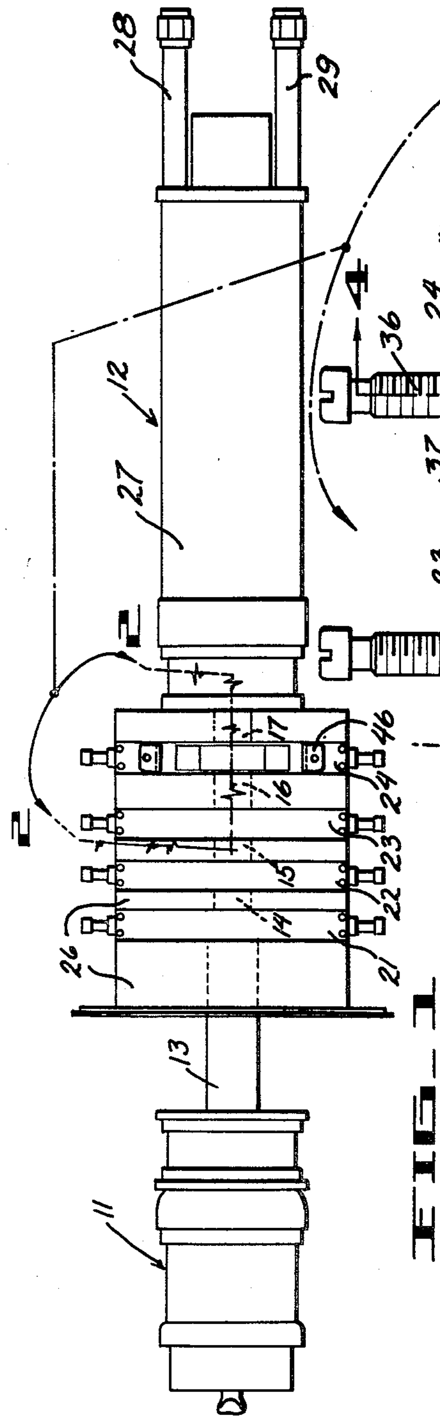

FIG. 1

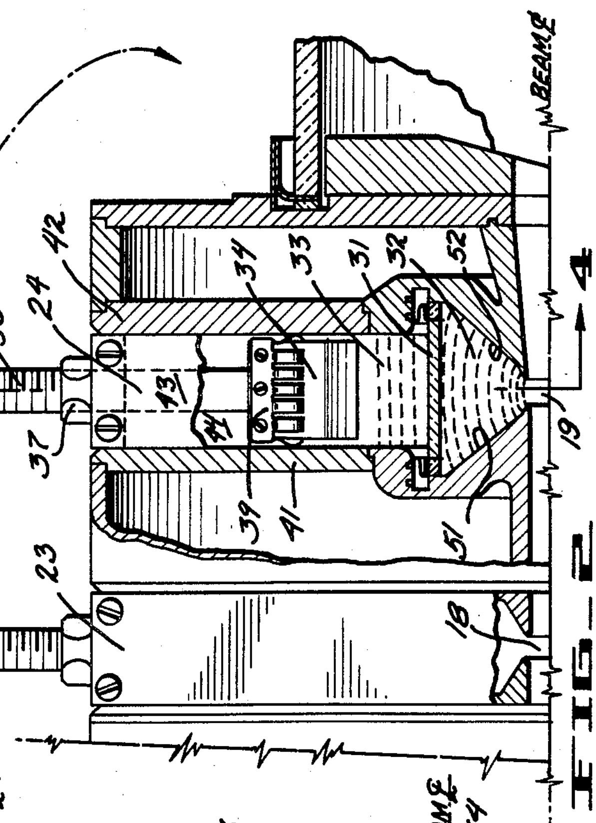

FIG. 2

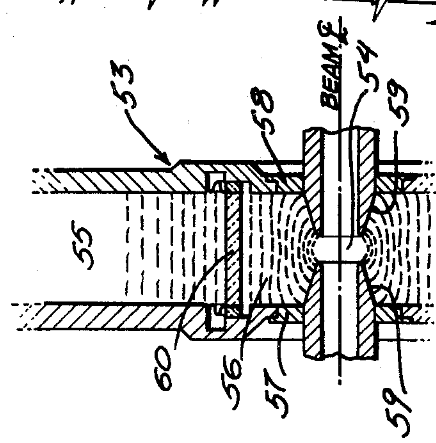

FIG. 3 PRIOR ART

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CAVITY RESONATOR FOR KLYSTRON TUBE

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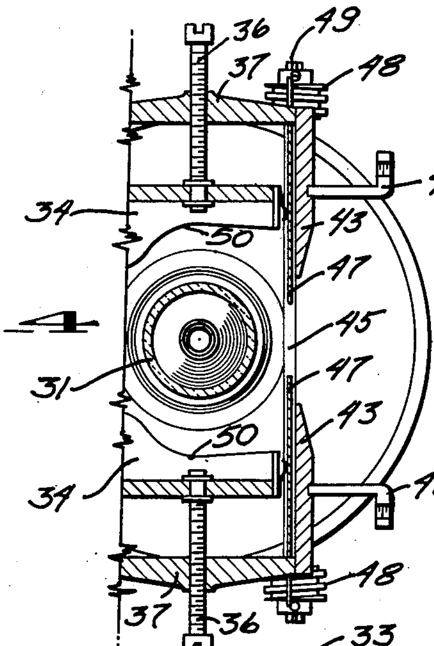

FIG. 4

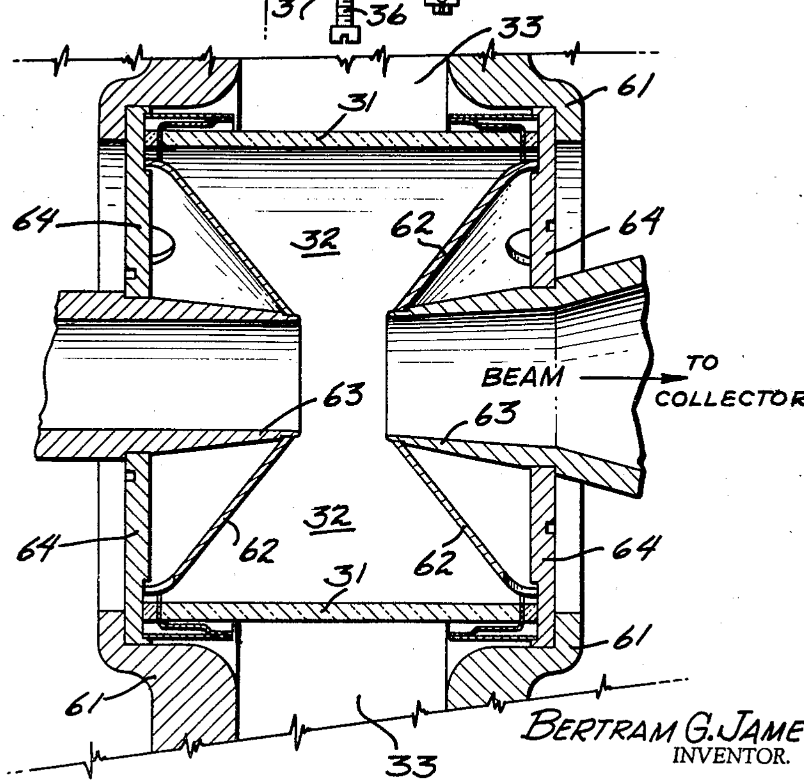

FIG. 5

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CAVITY RESONATOR FOR KLYSTRON TUBE

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9 Claims. (Cl. 315—5.46)

This invention relates generally to beam tubes such as klystrons which employ cavity resonators and more particularly to an improved cavity resonator structure for such tubes.

In one type of klystron tube the cavity resonators associated with the various gaps are made up of two parts: a first part which is internal to the evacuated envelope, and a second part which is external to the evacuated envelope and which carries the tuning means. A cylindrical dielectric window forms a part of the evacuated envelope and provides means for coupling energy from the internal portion of the cavity to the external portion. A tuning means within the cavity determines the resonant frequency thereof.

The configuration of the internal portion of prior art cavities is such that electric fields having relatively high components extending radially outward from the gap are set up at the gap. These radial field components tend to cause the secondary electrons produced by the impingement of primary electrons on some inner surface of the cavity to be directed toward and bombard the dielectric window. The bombardment of the window causes heating of the window which often results in the cracking thereof and the consequent loss of the vacuum within the tube.

Furthermore, the electric field configuration within the cavity is such that high voltage gradients exist at the window. This causes further heating of the window due to the high R.F. losses in the window and thus increases the danger of the cracking of the window, resulting in destruction of the vacuum within the tube. In addition, the energy loss in the window reduces the Q of the cavity.

It is an object of the present invention to provide a klystron having an improved cavity resonator structure.

It is another object of the present invention to provide a klystron having a resonant cavity which includes portions external and internal to the evacuated envelope of the klystron with a dielectric window coupling the two portions, in which the electric fields in the cavity are such that the heating of the dielectric window is reduced.

A more specific object of the invention is to provide a klystron having a resonant cavity including internal and external portions coupled by a dielectric window, in which electron bombardment of the window is reduced and the voltage gradient across the length of the window is reduced.

Referring to the drawing:

Figure 1 is an elevational view of a four cavity klystron tube;

Figure 2 is an enlarged view, partly in section, of the portion 2—2 of Figure 1;

Figure 3 is a sectional view schematically showing a cavity resonator in accordance with the prior art;

Figure 4 is a sectional view taken along the lines 4—4 of Figure 2; and

Figure 5 is a sectional view showing another embodiment of the novel cavity resonator.

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Referring to Figure 1 of the drawing, a klystron tube with cavity resonators in accordance with the subject invention is illustrated. The tube comprises a generally cylindrical envelope having an electron gun 11 at one end and a water-cooled collector 12 at the other end. The electron beam is projected from the electron gun to the collector and passes through a drift tube made up of a plurality of metallic sections 13, 14, 15, 16 and 17 which extend axially of the tube and are spaced from each other to form four gaps of which 18 and 19 are shown in Figure 2. Each of these gaps is bridged by a resonant cavity structure. Thus, four cavities 21, 22, 23 and 24 are shown. A suitable cooling jacket 26 surrounds the drift tube portions between the various tuning sections. Similarly, a cooling jacket 27 surrounds the collector 12. Water or other suitable cooling fluid may be introduced into the collector jacket 27 at the inlet and outlet connections 28 and 29. Suitable inlet and outlet connections (not shown) are provided for the jacket 26.

The resonant cavities are made up of two parts: an inner part which is within the evacuated envelope, and an outer part which is external to the evacuated envelope and carries the tuning means. Dielectric windows 31, one of which is shown, form a portion of the evacuated envelope and provide means for coupling energy from the internal portion 32 of the resonant cavity to the external portion 33. The windows surround the associated gaps and have their ends suitably sealed to the adjacent wall portions of the resonant cavity. Seals of this type are known in the art and will not be described in detail. Tuning means 34 are carried in the external portion of the resonant cavity as previously described.

The above described elements of the tube function in a manner well known for klystron tubes. Namely, an electron beam from the gun 11 is accelerated by positive potential on its anode (not shown) and passes through the drift tube past the interaction spaces provided by the gaps, and finally terminates on the collector 12. The resonant cavities 21—24 serve as the frequency determining elements of the device. As previously described, the tuning cavities receive movable tuning plungers which serve to tune the cavity over a particular frequency range. The tube illustrated may function as an amplifier with the input signal for modulating the electron beam fed into the resonant cavity 21 and the amplified radio frequency output taken from the resonator 24 in accordance with the usual practice in four-cavity type klystrons.

The tuning means 34 are moved by the tuning screws 36 which are threadably received by the end plate 37. The other ends of the tuning screws 36 are rotatably secured to the tuning means 34. The tuning means 34 may be any suitable type of tuning plunger. It may, for example, carry contact members 39 which engage the adjacent walls of the cavity (Figures 2 and 4). One of the walls 43 includes adjustable inductive iris opening 45 which serves to couple energy from the cavity resonator portion into an associated waveguide secured to the flanges 46. Adjustable diaphragms 47 are driven towards and away from one another by the lead worms 48 secured to ends of the shaft 49 to control the iris opening 45.

The tuning doors 34 are of open box-like construction and include end portions 50 having suitable configuration whereby they do not interfere with the opening 45 as they are moved.

A novel cavity resonator in accordance with the invention is shown in detail in Figure 2. The external portion 33 of the cavity includes a pair of parallel walls 41 and 42. The internal portion 32 includes walls having inner surfaces 51 and 52 which are spaced from and facing each other. Each of the surfaces defines the surface of a truncated cone with its axis coincident with the axis of the associated drift tube. The apex of the cone extends to a portion of the cavity adjacent the gap 19 and the base of the cone extends to a portion of the cavity adjacent the ceramic window 31.

The advantage of a cavity according to this invention can best be understood by comparison with a cavity according to the prior art.

Referring to Figure 3, a prior art cavity 53 is shown associated with drift tube sections forming a gap 54. The external portion of the cavity 55 includes parallel wall portions similar to wall portions 41 and 42 of Figure 2 and which receive a tuning means (not shown) similar to that shown in Figure 2. The internal portion 56 of the cavity 53 is separated from the external portion 55 by means of a ceramic cylinder 60. The internal portion 56 of the cavity 53 comprises parallel wall portions 57 and 58 which are each sealed to a drift tube section. The ceramic cylinder 60 serves as a window, coupling R.F. energy from the internal portion 56 to the external portion 55 of the cavity 53. Thus, a cavity 53 according to the prior art comprises a pair of parallel walls through which drift tube sections project toward each other to form a gap 54. This structure results in a concentration of the electric field in the cavity 53 at the gap 54 due to the close spacing of the drift tube sections. Such concentration of the electric field at the gap 54 is desirable since it provides for increased interaction between the electric field in the cavity and the electron beam of the klystron as such beam traverses the gap 54.

However, if the electric field within the cavity is plotted it will be found to have the distribution represented generally by the dotted lines in Figure 2. Due to the concentration of the electric field at the gap 54 the field adjacent the gap will have a strong radial component, as indicated by the curvature of the dotted lines adjacent such gaps 54. Due to space charge effects, primary electrons in the beam will tend to spread and enter the cavity rather than proceeding on down the drift tube. Some primary electrons at the edge of the beam will actually bombard the ends of the drift tube sections adjacent the gap 54. Such bombardment of the ends of the drift tube sections will result in the release of large numbers of secondary electrons. Due to the radial component of the electric field within the cavity, the secondary electrons produced by the bombardment of the drift tube will be accelerated toward the ceramic window 60. The bombardment of the ceramic window 60 by the electrons, as mentioned above, will result in localized heating thereof and possible cracking of the ceramic window due to the temperature gradient established thereacross.

In order to decrease the effects described above it was customary in prior art cavities to provide the ends of the drift tube sections adjacent the gap with knife edges as for example by tapering the ends of the drift tube as shown at 59. According to the theory of the prior art, the purpose of such knife edges was to minimize electron bombardment of the ends of the drift tube sections and thus reduce the number of secondaries produced. However, the radial components of the electric field adjacent the gap remained substantially unchanged.

Referring again to Figure 2 and particularly to the dotted lines representing the electric field distribution in the cavity there shown, the advantages believed to be obtained by the cavity according to the subject invention are readily apparent. It will be seen that the radial component of the electric field adjacent the gaps 19 (as represented by the curvature of the dotted lines) is much smaller than in the prior art cavity 53. Thus, due to the decreased radial components in the electric field, the acceleration of secondary electrons toward the ceramic window 31 is decreased and thus the bombardment and consequently the heating of the ceramic window is reduced.

Furthermore, if we compare a cavity according to the subject invention with one according to the prior art (such as 53), each being designed to cover the same frequency range, additional advantages will be observed. With respect to the design of a cavity according to the subject invention to cover a given frequency range, it should be pointed out that although the inclusion of the truncated cone surfaces 51 and 52 in the internal portion 32 of the cavity represents a substantial decrease in volume compared to straight walls such as 57 and 58 in the prior art, the resonant frequency of internal portion 32 is not necessarily increased as might be expected. This is due to the fact that the inductance introduced into the portion 32 by the surfaces 51 and 52 is less than that introduced into the portion 56 of the cavity 53 by the surfaces formed by the drift tube and end walls 57 and 58 due to the fact that the electrical path is shorter along the surfaces 51 and 52, whereas the capacity introduced into the portion 32 by the opposed surfaces 51 and 52 is greater than that introduced into the portion 56 by the end walls 57 and 58 due to the closer average spacing of surfaces 51 and 52. Thus, the decrease in inductance in the portion 32 of the cavity according to the subject invention tends to be compensated by the increase in capacitance.

The above described design features of a cavity according to the subject invention enables the use of a longer ceramic window while maintaining the same or an increased tuning range. In other words, by employing truncated conical surfaces 51 and 52 it is possible to use a longer ceramic cylinder 31 without appreciably affecting the tuning range of the cavity or even with an increase in the tuning range. The use of a longer ceramic window is desirable since the voltage across the window will be distributed over a greater length thus decreasing the voltage gradient and therefore the danger of arcing. In addition, the amount of heating per unit volume of the ceramic will be decreased in accordance with the increased volume of ceramic, thus decreasing the possibility of the ceramic cracking due to heating effects. Increases in ceramic length of as much as 50% have been obtained according to the subject invention with no appreciable change in frequency range. Thus, the voltage gradient and heating of the ceramic may be correspondingly reduced without appreciable change in the tuning range of a cavity by constructing such cavity in accordance with the subject invention.

Referring to Figure 5, another resonant cavity is shown. The cavity includes an external portion 33 and an internal portion 32. The cavity shown includes walls 61 forming a part of the external cavity which may be suitably clamped onto the klystron tube rather than being formed integral therewith. The conical wall portions are formed by conical sheet metal members 62 having their apexes suitably secured to the adjacent portions of the drift tube 63 and their bases suitably secured to the walls 64. A ceramic window 31 is suitably sealed to the adjacent wall portions in a manner well known to the art, and provides coupling between the internal and external portions of the cavity, as previously described.

Thus, it is seen that an improved cavity resonator is provided for klystron tubes having internal and external cavity portions with a dielectric coupling therebetween. The configuration of the cavity resonator permits the use of longer cylindrical dielectric windows. A field configuration in which the R.F. losses in the windows are reduced and electron bombardment of the window is minimized is also provided. Further, the configuration provides a tuning cavity having an increased "Q" and improved tuning characteristics.

What is claimed is:

1. An electron tube having an evacuated envelope, said electron tube comprising a drift tube including a plurality of sections, spaced from each other to form at least one gap, an electron gun at one end of said tube serving to project a beam of electrons through said drift tube, a collector electrode at the other end of said drift tube and serving to receive said electron beam, a cavity reso-

nator surrounding said gap, a dielectric window sealed within said cavity resonator and forming a part of said evacuated envelope, said dielectric window dividing said cavity resonator into two portions and serving to electrically couple said portions, the portion of said cavity resonator external to said evacuated envelope including a pair of spaced walls having internal surfaces parallel to each other and perpendicular to the axis of said drift tube, the portion of said resonator internal of said envelope having surfaces which define a pair of truncated cones one on each side of said gap, said truncated cones being coaxial with said drift tube and having their bases adjacent opposite ends of said dielectric window and their apexes extending towards one another, said pair of truncated cones being coaxial with each other and with said drift tube, the spacing between said pair of walls being less than the distance between the bases of said truncated cones.

2. A cavity resonator comprising an evacuated portion and a portion which is not evacuated, a dielectric cylinder separating said portions from each other serving as a vacuum tight envelope member therebetween and coupling electrical energy from one portion to the other, the portion of said cavity internal of said dielectric cylinder comprising a pair of truncated cones with their bases adjacent opposite ends of said dielectric cylinder and their apexes extending toward each other, said pair of truncated cones and said dielectric cylinder being coaxial, the bases of such cones having a diameter approximately equal to the internal diameter of the dielectric cylinder, and the external portion of such cavity comprising a pair of spaced walls, one adjacent each end of said dielectric cylinder, the length of said dielectric cylinder being greater than the spacing between said pair of walls.

3. A cavity resonator comprising a first portion and a second portion, said first portion being contained within a dielectric cylinder and comprising a pair of truncated cones coaxial with said dielectric cylinder, the apexes of said truncated cones extending toward each other, the bases of said cones being adjacent opposite ends of said dielectric cylinder and having a diameter approximately equal to the internal diameter of said dielectric cylinder, the second portion of said cavity comprising a pair of spaced parallel walls external of said dielectric cylinder and one wall adjacent each end of said dielectric cylinder, the length of said dielectric cylinder being greater than the spacing between said pair of walls.

4. A beam tube comprising an electron gun serving to project a beam of electrons, an electrode spaced from said gun, an R.F. interaction means interposed between said gun and said collector and having an axis along which said beam passes through said interaction means, said interaction means including an interaction gap, a cavity resonator surrounding said gap, said cavity resonator having a first portion and a second portion separated by a dielectric window, said dielectric window serving to electrically couple the first and second portions of the cavity resonator, said second portion of the cavity resonator including spaced walls having spaced parallel internal surfaces, and said first portion including internal surfaces which define a pair of truncated cones with their apexes extending towards one another and their bases extending to adjacent opposite ends of the dielectric window and having axes coincident with said axis along which said beam passes, the spacing between said parallel internal walls being less than the distance from the base of one of said pair of truncated cones to the base of the other of said pair of truncated cones.

5. A klystron tube having an evacuated envelope, said klystron tube comprising an electron gun serving to project a beam of electrons, a collector spaced from said gun and adapted to receive said electron beam, a drift tube interposed between said gun and said collector and through which said beam passes, said drift tube including a plurality of sections forming at least one gap, a cavity resonator surrounding said gap, said cavity resonator having a first portion internal of said evacuated envelope and a second external portion, and a dielectric window forming a part of the evacuated envelope and serving to electrically couple the first and second portions of the cavity resonator, said second portion of the cavity resonator including spaced parallel walls forming a box-like enclosure having a given transverse dimension, and said first portion including internal surfaces which define a pair of cones coaxial with said drift tube and with their apexes extending transversely of said box-like enclosure toward one another and their bases extending to opposite ends of the dielectric window, said given transverse dimension being less than the distance between the bases of said pair of truncated cones, and tuning means movable toward and away from the dielectric window carried in the external portion of the cavity.

6. A klystron tube having an evacuated envelope, said klystron tube comprising an electron gun serving to project a beam of electrons, a collector spaced from said gun and adapted to receive said electron beam, a drift tube interposed between said gun and said collector and through which said beam passes, said drift tube including a plurality of sections forming at least one gap, a cavity resonator surrounding said gap, said cavity resonator having a portion external of the evacuated envelope and a portion internal to the evacuated envelope, a ceramic cylinder forming a part of the evacuated envelope and serving to electrically couple said first and second portions of said cavity resonator, said internal portion including interior wall surfaces which define the surfaces of a pair of truncated cones coaxial with said drift tube and with the apexes of the cones extending towards one another, the bases of said cones being adjacent opposite ends of said ceramic cylinder and having a diameter substantially equal to the internal diameter of said ceramic cylinder, said external portion of said cavity resonator comprising a pair of spaced parallel walls, said ceramic cylinder having a length greater than the spacing between said parallel walls.

7. A klystron tube having an evacuated envelope, said klystron tube comprising an electron gun serving to project a beam of electrons, a collector spaced from said gun and adapted to receive said electron beam, a drift tube including a plurality of sections forming a plurality of gaps, cavity resonators surrounding each of said gaps, said cavity resonators having a first portion internal of the evacuated envelope and a second portion external thereto, and dielectric cylinders forming a part of the evacuated envelope surrounding said gaps and coaxial with said drift tube, said dielectric cylinders serving to electrically couple the first and second portions of the cavity resonator, the first portion of at least one of said cavity resonators including interior surfaces which define a pair of cones having their axes coincident with the axis of the drift tube and their apexes extending towards one another, the bases of each pair of said cones being adjacent opposite ends of one of said dielectric cylinders and having diameters substantially equal to the internal diameter of said dielectric cylinder, the second portion of said cavity resonators including a pair of walls defining spaced parallel internal surfaces perpendicular to the axis of said drift tube, the length of said dielectric cylinders being greater than the spacing between said internal surfaces, and tuning means movable towards and away from the dielectric window carried in the external portion of said cavity.

8. A klystron tube having an evacuated envelope, said klystron tube comprising an electron gun serving to project a beam of electrons, a collector spaced from said gun and adapted to receive said electron beam, a drift tube including a plurality of sections forming a plurality of gaps, cavity resonators surrounding each of said gaps, said cavity resonators having a first portion internal of

the evacuated envelope and a second portion external thereto, and dielectric cylinders forming a part of the evacuated envelope surrounding said gaps and serving to electrically couple the first and second portions of said cavity resonators, the second portion of said cavity resonators including a pair of walls defining spaced parallel surfaces, and the first portion of at least one of said cavity resonators including interior surfaces which define a pair of truncated cones having their axes coincident with the axis of the drift tube and their apexes extending towards one another, the bases of said cones extending outwardly to adjacent opposite ends of the dielectric window, the spacing between the bases of the conical surfaces being greater than the spacing between said parallel surfaces.

9. A beam tube as claimed in claim 4 wherein a tuning means movable toward and away from the dielectric window is carried in the external portion of the cavity.

References Cited in the file of this patent

UNITED STATES PATENTS

2,250,511	Varian et al.	July 29, 1941
2,413,244	North	Dec. 24, 1946
2,415,749	Malter	Feb. 11, 1947
2,629,066	Eitel et al.	Feb. 17, 1953
2,824,289	Murdock	Feb. 18, 1958