The present invention relates in general to high frequency tubes and more particularly to a novel rugged, high power, continuous wave, UHF, broadband amplifier useful, for example, in applications such as navigation and communication systems, as a driver for a linear accelerator, and the like.

In the past a number of difficulties have been encountered in the construction of high power, UHF, broadband amplifiers such as klystrons. It has been difficult to fabricate quickly and easily rugged, high frequency, high power klystron tubes which can be baked during processing without damaging the moving parts thereof. In the past, during the bake-out step of processing the tube certain delicate parts of the tube such as the threads on the tuning screws were adversely affected. Also, prior tubes have not had sufficiently adequate liquid cooling of critical parts such as the tuner mechanisms. An additional problem has been to maintain the gap impedance in the output gap constant over the wide tuning range of the tube.

A major limitation to all high power tubes has been the output window which must be powerful enough to withstand the high pressures generated in these tubes and still sufficiently broadband to pass frequencies over a wide tuning range. In the past high power broadband waveguide windows have been constructed according to a design set forth in U.S. Patent 2,958,834 of Symons et al., assigned to the assignee of the present invention. According to the teachings of that patent, a circular waveguide window is sealed in circular waveguide positioned between two rectangular waveguides with a net capacitive discontinuity existing at the junction of the waveguides. Output window designs, according to the teachings of that patent, have been relatively broadband, having bandwidths on the order of 30%. However, certain resonant modes exist at discrete frequency regions across the frequency band passed by windows designed according to the teachings of that patent, and in order to prevent window failure the frequency range of the electron tube has been limited to a range between resonant modes. For example, for the frequency band centered about 870 megacycles only a 17% bandwidth could be obtained between undesired resonant modes. When prior tubes operated at the frequency of these various resonant modes power would be dissipated in the window and window support structure to either crack the window or create a leak in the window or supporting structure.

According to the present invention, a high frequency, high power, broadband amplifier is provided which is easily constructed, is rigid, and is broadband. The teachings of the present invention contemplate a high frequency tube wherein the body of the tube is made up of a number of punch press cups which can be joined together to form a cavity subassembly, and then a plurality of cavity subassemblies can be joined together to form the body subassembly. Also, according to the teachings of the present invention, a removable water-cooled tuning mechanism is provided for the tube whereby no critical parts of the tuner mechanism are processed with the tube. Also, in order to provide optimum beam loading for the klystron over the wide tuning range of the tube a tapered section is provided in the output waveguide which produces a frequency-dependent impedance at the waveguide side, the output iris of the tube which compensates for the impedance changes in the output cavity as the tuner is tuned to vary the output frequency of the tube over the band of the tube. Conduction means are provided at the output iris to conduct heat to cooling means for preventing overheating of the structure around the output iris. And the broadband output window is provided by positioning a circular dielectric window within a circular section of guide positioned between two parallel circumscribed partially rectangular high impedance guide sections. All undesired modes in the region of the output window of the tube are perturbed by positioning mode suppressive means in the region around the output window. A typical UHF broadband amplifier klystron tube according to the present invention is on the order of 5 ft long and about 250 pounds in weight and can supply more than 100 kilowatts of continuous wave power over more than a 26% frequency band between 755 and 985 megacycles.

The object of the present invention is to provide an improved high frequency klystron amplifier tube apparatus which is relatively simple of construction, relatively rigid and which will have long operating life while delivering high average R.F. power output over a wide frequency range.

One feature of the present invention is the provision of a punch press cavity construction wherein individual cavities can be formed in subassembly form and the cavity subassemblies can be secured together to form the body assembly.

Another feature of the present invention is the provision of a removable waveguide tuning mechanism and a cooling tube subassembly which is cooled by a flowing fluid and which is easily removable from the rest of the tube apparatus so that the tube can be processed without the tuner mechanism.

Another feature of the present invention is the provision of an output waveguide section provided with tapered portion on the waveguide to produce a frequency dependent impedance for the output cavity so that the optimum impedance is maintained at the output gap of the tube over the frequency range of the tube.

Another feature of the present invention is the provision of conduction means at the output iris of an electron tube for conducting heat from the output iris to cooler means for reducing the temperature of the structure around the output iris.

Still another feature of the present invention is the provision of a novel broadband output window assembly which does not support spurious resonant modes in the frequency band of interest wherein a circular dielectric window is positioned between two semicircular and semi-rectangular waveguide portions in a rectangular waveguide transmission line.

Still another feature of the present invention is the provision of a novel waveguide window assembly wherein dielectric window is positioned in a resonant structure which will support desired and undesired resonant modes and conduction means are provided orthogonal to the electric field lines of the desired resonant mode whereby undesired resonant modes are suppressed.

Still another feature of the present invention is the provision of a novel waveguide window assembly wherein current attenuating means are provided in the paths of the currents of undesired modes without substantially tenuating the currents of the desired mode whereby undesired modes will be suppressed.

Other features and advantages of the present invention will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein FIG. 1 is a longitudinal view showing the multicavit klystron amplifier apparatus of the present invention.
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FIG. 2 is an enlarged cross sectional view of a portion of the structure of FIG. 1 delineated by the line 2—2.

FIG. 3 is a cross sectional view of a portion of the structure of FIG. 2 taken along the line 3—3 in the direction of the arrows,

FIG. 4 is an enlarged cross sectional view of a portion of the structure of FIG. 3 taken along line 4—4 in the direction of the arrows,

FIG. 5 is a reduced cross sectional view of a portion of the structure shown in FIG. 2 taken along line 5—5 in the direction of the arrows,

FIG. 6 is a cross sectional view of a portion of the structure shown in FIG. 5 taken along line 6—6 in the direction of the arrows,

FIG. 7 is an end view, partially broken away, of a portion of the structure shown in FIG. 1 taken along line 7—7 in the direction of the arrows,

FIG. 8 is an enlarged cross sectional view of a portion of the structure shown in FIG. 7 taken along line 8—8 in the direction of the arrows,

FIG. 9 is a side view of an alternative output window assembly, and

FIG. 10 is a fragmentary view of FIG. 8 delineated by lines 10—10 depicting the septum mode suppression nbodiment.

Referring now to the drawings there is shown in FIG. 1 the external configuration of the novel tube apparatus f the present invention. More specifically, a segmented tubular cathode assembly 11 provides a source of electrons which are formed into a pencil-like beam and projected longitudinally of the tube apparatus. A plurality of circular cavity resonators including an input cavity 2, second, third, and fourth buncher cavities 13, 14, and 5 and an output cavity 16 are centrally apertured to allow the passage of the pencil-like beam of electrons therethrough.

Each of the cavity resonators 12—16 is tunable over a wide range via a novel tuner assembly 17 which will be more fully described below. The beam after passing through the output cavity resonator 16 is collected in a collector assembly 18. The thermal energy generated by the impinging electrons within the collector 18 is carried away by a fluid coolant circulated through the collector assembly 18.

R.F. signal energy, which it is desired to amplify, is fed to the input cavity 12 via a vacuum coaxial connector assembly 19. The signal energy velocity modulates the beam as it passes through the input cavity 12. The velocity modulation of the beam is transformed into current density modulation in the drift space between the input cavity 2 and the first buncher cavity 13. Buncher cavity resonators 13, 14, and 15 further velocity modulate the beam to produce greater current density modulation of the beam that exits from the output cavity 16. The output cavity 16 extracts R.F. energy from the current density modulated beam.

The output R.F. energy is coupled outwardly of the output cavity 16 via a rectangular waveguide 21 and fed to a suitable load, not shown, such as, for example, an antenna. The waveguide 21 is sealed in a vacuum-tight manner by a novel vacuum window assembly 22 which is described in greater detail below. A segmented magneticolenoid 23 shown in phantom circumscribes the central art of the tube apparatus, containing the cavity resonators, for providing a strong axial magnetic field longitudinal of the tube from an anode pole piece 24 adjacent the cathode assembly 11 to a collector pole piece 5 adjacent the collector assembly for confining the pencil-like beam of electrons.

The novel cavity construction of the present invention is shown in greater detail in FIGS. 2 and 3. More specifically, the input cavity 12 and the buncher cavities 13, 14, and 15 a capacitive tuner plate 31 as of, for example, stainless steel and in the form of the top and sides of a septum is supported on one closed end of a flexible metallic bellows 32 as of, for example, stainless steel.

Within the bellows 32 on the opposite side of the closed end thereof from the tuner plate 31 is secured, as by brazing, a nut 33 as of, for example, stainless steel for attaching the novel tuner actuating means described in detail below.

At its open end the bellows 32 is secured in a vacuum-tight manner to one end of a punched (hydro-formed) bellows support cup 34 as of, for example, stainless steel, which surrounds the portion of the bellows 32 extending outward from the closed end of the cavity. The opposite end of the bellows support cup 34 is flared and cut to conform to the cylindrical outside surface of a flanged open ended, punched, main cavity cup 35 as of, for example, stainless steel the axis of which is aligned with the axis of the electron tube. The bellows support cup 34 is secured to the main cavity cup 35 in a vacuum-tight manner such as by brazing. The main cavity cup 35 is apertured within the bellows support cup 34 to receive the bellows 32 in the cavity resonator. A mounting ring 36 as of, for example, stainless steel, is secured to the base of the bellows support cup 34 for securing the tuner actuating mechanism onto the bellows support cup 34.

The bottom end of the main cavity cup 35 is apertured and the flanged top open end of the cup 35 is closed by an apertured cavity header disc 37 as of, for example, stainless steel. Drift tubes 38, such as copper, project into the cavity through the apertures in the main cavity cup 35 and the header disc 37 to provide an interaction gap substantially midway of the cavity.

A flanged open ended, punched, coolant cavity cup 39 is secured, as of, for example, stainless steel, apertured in its base has its base secured such as by brazing to the base of the main cavity cup 35 surrounding the drift tube 38 and its flanged open end secured, such as by brazing, to the header disc 37 of the next adjacent cavity. The coolant cavity cup 35 is divided along a diameter by a septum 41 as of, for example, stainless steel, and is provided with inlet and outlet coolant fluid fittings 42 and 43, respectively, for passing a coolant fluid therethrough. The septum 41 is made up by a segment on each side of the drift tube 38. Each segment is made up of two partially overlapping pieces 41’ and 41” which are initially secured to the coolant cavity cup 39 and the header disc 37, respectively, during fabrication of the tube. The segment pieces 41’ and 41” are then joined together, as by brazing, during construction of the cavity assembly and allow for different tolerances in the parts of the cavity subassembly.

In each drift tube 38, longitudinal grooves 44 are cut extending from adjacent one end of the drift tube 38 to the adjacent the other end thereof. An annular groove 45 is provided adjacent each end of the drift tubes 38 connecting all of the longitudinal grooves 44. A sleeve 46 of the same material as the drift tubes 38 is slid over each end of the drift tubes 38 which project into one of the cavities, and the sleeves 46 are secured to the drift tubes 38 in a vacuum-tight manner thereby defining fluid coolant channels in the grooves 44 and 45. For ease in assembling the drift tubes, a radial projecting ridge 47 is provided at one end of each drift tube 38 so that one of the two sleeves 46 for each drift tube can be slid over the drift tube 38 and seated against the ridge 47 before the drift tube 38 is inserted into the apertures in the main cavity cup 35, the coolant cavity cup 35 and the cavity header disc 37 at which time the other sleeve 46 is added.

In order to cool the drift tubes 38, cooling fluid directed by the inlet fitting 42 into the coolant cavity cup 39 which is divided into two separated sides by the septum 41, passes through the longitudinal grooves 44 to the ends of the drift tube 38, passes down the other side of the drift tube 38 through the longitudinal grooves 44 to the other side of the coolant cavity cup 39 and out the outlet fitting 43.

The mutually opposing free end portions of the drift tubes 38 within the cavities are provided with serrations
to prevent occurrence of multipactor which would adversely effect the power output of the tube apparatus.

The novel cavity construction permits easy assembly of rugged individual cavity subassemblies in the manner set forth below, and then these cavity subassemblies are joined together to form the rugged integral body assembly.

The individual cavity subassemblies are formed by first joining, by spot welding, the septum pieces 41 and the water fittings 42 and 43 to the coolant cavity cup 39. The coolant cavity cup 39 is then joined, by spot welding, to the main cavity cup 35 which has joined thereto, as by spot welds, the bellows support cup 34 with the mounting ring 36 secured thereto. Then the header disc plate 37 with the septum pieces 41" secured thereto as by spot welds is secured, as by spot welding, over the open end of the coolant cavity cup 39. This entire assembled structure is then sealed together in a vacuum-tight manner as by brazing in a furnace. The drift tube 38 with one sleeve 45 positioned therein abutting the ridge 47 is slid through the apertures in the main cavity cup 35, the coolant cavity cup 39, and the header disc plate 37 and the other sleeve 46 positioned thereon. Then the bellows 32 with the tuner plate 31 and the nut 33 joined thereto, as by spot welds and then brazes, is secured to the bellows support cup 34 as by an R.F. brazed complete the cavity subassembly. The required number of these cavity subassemblies are secured together to form the body assembly of the tube.

Referring now to FIGS. 2, 3, and 4, the tuner actuating mechanism includes a cup-shaped tuner support 51 as of, for example, cast bronze, which is fixedly secured at its open end in a water-tight manner to the mounting ring 36 by a plurality of bolts 52 and an O-ring 53. The tuner support 51 is provided with a re-entrant opening 50 adapted to slideably receive therein the bellows 32 and the bellows support cup 34, and the tuner support 51 also includes a hollow cylindrical tuner bearing support portion 54 axially thereof which extends within the bellows 32. On two opposing sides of the tuner support 51 the re-entrant opening 50 is enlarged outside the bellows support cup 34, inside the bellows 32, and at the outer end of the bellows support cup 34 and the bellows 32 (see FIGS. 3 and 4). Inlet and outlet coolant fluid fittings 55 and 56, respectively, are provided on the tuner support 51 and communicate with these enlarged portions of the opening 50.

A stepped diameter bore is provided within the tuner bearing support portion 54 of the tuner support 51, and a hollow tuner bearing member 57 as of, for example, bronze, with a threaded bore therethrough and with a stepped diameter exterior surface is inserted within the bore of the tuner support 51. One end of the tuner bearing member 57 is screwed into the nut 33 on the closed end of the bellows 32. A scaling plug 58 such as Teflon is inserted within the bore of the tuner bearing member 57 which is a metallic set screw 59 is screwed within the threaded bore in the tuner bearing member 57 to compress the plug 58 thereby locking the tuner bearing member 57 to the nut 33 and creating a water-tight seal. A hollow cylindrical bushing 61, such as Teflon, is contained within the end of the tuner bearing support portion 54 of the tuner support 51 by means of a metallic snap ring 62 thereby providing a sliding bearing surface for the tuner bearing member 57 within the tuner support 51. A tuner drive screw 63 as of, for example, stainless steel, threadably engages the threads in the bore through the tuner bearing member 57 for moving the tuner plate 31 for adjustment of tuner 51 in and out of the cavity 38. The outer end of the tuner drive screw 63 is captured against rectilinear translation by a shoulder in the bore through the tuner support 51 and by a metallic snap ring 64.

By this construction a removable water-cooled tuning mechanism is provided. The electron tube with only the bellows 32, the bellows support cup 34, and the nut 33 can be baked during the processing of the tube with a dummy tuner actuating mechanism holding the tuner in a fixed position. After the tube has been processed or evacuated, thedummy is removed and the tuner actuating mechanism can be secured by greasing the tuner support 51 to the mounting ring 36, screwing the tuner bearing member 57 into the nut 33, locking the tuner bearing member with the nut 33 by means of a sealing plug 58, and then screwing the tuner drive screw 63 into the tuner bearing member 57 and locating the drive screw 63 in place with the snap ring 64. By the provision of this removable tuning mechanism none of the critical moving parts of the tuner mechanism are damaged during processing of the tube. Also, the cooling fluid will cool the entire tuner mechanism without coming in contact with the critical moving parts. A removable tunab mechanism can also be provided by threading the bore of the tuner bearing member 57 immediately adjacent the closed end of the bellows 32 and providing an oncandy threaded stub instead of the nut 33 for screwin and locking the tuner bearing member 57 to the back side of the closed end of the bellows 32.

In order to cool the tuner assembly, coolant fluid, such as water, is passed in the inlet fitting 55, around the bellows support cup 34 and the bellows 32, down the bellows 32 to the closed end of the bellows where it passes to the other sides of the bellows and out the outlet fitting 56. Some of the coolant fluid will travel around the convolutions of the bellows so that the entire bellows 32 is in direct contact with the coolant fluid.

Due to the high field strength existent in the output cavity 16, certain structure in this cavity is modified for that of the other cavities. The output drift tube 38' (FIG 2) tapers outwardly in the direction of the collective assembly 15 to decrease interception of the divergent electron beam and is fluid-cooled by means of longitudinal and annular grooves 44' and 45', respectively, similar to those on the drift tubes 38 of the other cavities.

The output cavity 35' is open ended and reverse in direction from those of the other cavities of the tube whereby the output cavity 16 and collector pole piece 25 can be assembled together in one subassembly. This subassembly can then be mounted on the stack of other cavity assemblies and then the collector assembly is mounted thereon.

Referring now to FIGS. 2, 5, and 6, an iris opening 71 is milled in the side of the output cavity cup 35' adjacent the collector pole piece 25 for coupling electro magnetic energy out of the output cavity 16. The side wall 72 of the output rectangular waveguide 21 is connected to the output main cavity cup 35' via tapering wall sections 73 which make an angle A with the waveguide side walls 72 and along with flat end walls 71 reduce the wide dimension of the waveguide 21 to the size of the output cavity 16. The waveguide 21 is additionally provided with a step transformer 74 between the output cavity 16 and the window assembly 22 (see FIGS. 6 and 2).

Due to the change in field patterns as the output cavity is tuned, the shunt impedance of the output cavity drift tube gap and the coupling of the iris 71 vary across the tuning range of the electron tube. A certain fixed output gap impedance is required over this tuning range of the tube for optimum power transfer from the output cavity 16 to the output waveguide 21. The tapered walls 71 provide a frequency-dependent impedance at the waveguide side of the iris slot 71 which compensates for the
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The height of this waveguide with the tapered walls 73 is then matched to regular waveguide sizes with step transformer 74. Changing the angle of the tapered wall sections 73 changes their characteristic frequency-dependent impedance, and, thus, there is an optimum angle for any given tube. This angle can be determined by cut and try methods. The taper of these walls 73 effects the shunt reactive component presented to the iris 71 and also affects the length of the first section of the step transformer 74. The type of tube illustrated here operates at a center frequency of 870 mc. with more than 26% and width and power output greater than 100 kc. CW 16 tapered wall sections 73 makes an angle A of approximately 145° with the waveguide side walls 72.

By positioning the output iris 71 adjacent the collector pole piece 25, the solenoid 23 is able to come closer to the output pole piece 25 so that more uniform magnetic field strength is maintained in the output gap region or better beam focusing, and also a direct line is presented between the output cavity drift tube gap and the window assembly 22 to protect the window assembly from electron bombardment.

In order to provide sufficient cooling of the region surrounding the output iris 71 cooling members 75 of high heat conductive materials such as copper, are positioned along the side of the iris opening 71 to conduct the heat to the base of the output waveguide 21. Cooling fluid channels 76 are positioned around the output cavity 6 adjacent the pole piece 25 and in direct contact with the base of the waveguide 21 for conducting heat from the output cavity 35 and the cooling fluid for the body cooling of the tube as well as the drain to the base of the waveguide 21. The cooling fluid supplied to the tube apparatus at the conductor 77 (see FIG. 1) which directs the fluid to a manifold 78. From the manifold 78 fluid is piped to the inlet fitting 42 of the coolant cavity 39 for the input cavity 2, to the inlet fitting 55 of the tuner assembly 17 for cavity 14, and to the inlet fitting (not shown) of the cooling fluid channels 76. The cooling fluid from the input cavity coolant cavity 39 is piped on to other avities and the cooling fluid from the cavity 14 tuner assembly 17 is piped on to other tuner assemblies. Of the two cavities 17 in the tube apparatus as shown, only the tuner assemblies in the last two cavities are cooled since considerably more heat is dissipated in these two cavities than in the others. However, all of the tuner assemblies can be cooled, if desired.

Structural support is provided for the output waveguide 21 by a metallic angle bar 79, as of, for example, steel, which extends across the long side of the waveguide 21 see FIG. 1).

Referring now to FIGS. 7 and 8, the novel window assembly 22 which seals the output waveguide 21 includes a circular, gas-tight, wave permeable window 81 as of, for example, aluminum oxide (Al₂O₃) or quartz or other dielectric and whose diameter is less than the diagonal or largest dimension of the rectangular waveguide 21. The window 81 is sealed in a vacuum-tight manner to an annular window support cap 82 as of, for example, Kovar. The flange member 83 is mounted as by brazing on an axially projecting annular shoulder portion 84 of a first vide, annular, waveguide mounting flange 85 as of, for example, stainless steel. This first mounting flange 85 is soldered to a second wide, annular, waveguide mounting flange 86 as of, for example, aluminum, with the window 81, its support cup 82 and the flange member 83 supported under compression therebetween.

On the sides of each of the waveguide mounting flanges 85 and 86 opposite from the window 81 are respectively mounted, as by brazing, one end of high impedance waveguide sections 87 and 88 as of, for example, stainless steel and aluminum, respectively. These waveguiding sections 87 and 88 have a higher characteristic impedance than the waveguide 21. The other end of waveguide section 87 is joined as by brazing to the rectangular waveguide 21 while the other end of waveguide section 88 is joined as by brazing to an output waveguide flange 89 as of, for example, aluminum. These high impedance waveguide sections 87 and 88 are shaped to conform to at least the largest portions of both the rectangular waveguide 21 and the inner surfaces of the output waveguide flange 89 and the waveguide mounting flanges 85 and 86. Therefore, the cross section of these high impedance waveguide sections 87 and 88 is a rectangle with circular portions 92 in the sides thereof. Where the ends of these high impedance waveguide sections 87 and 88 are joined to the waveguide mounting members 85 and 86, the excess rectangular portions are blocked off whereas the excess circular portions are closed off by circular segment wall portions 93 and 94 where the high impedance waveguide sections 87 and 88 are joined to the waveguide 21 and the output waveguide flange 89, respectively.

The window 81, its supporting structure including the mounting flanges 85 and 86, and the high impedance waveguide sections 87 and 88 form a resonant structure which will support undesired resonant modes as well as transmitting the desired mode.

Mode suppression means are provided in the region adjacent the window 81 to prevent the existence of undesired resonant modes which will cause leaks in the window assembly or cause the window to crack. In the present tube apparatus a round metallic conducting bar 95 as of, for example, aluminum, is positioned in the middle of the rectangular portion 91 of the high impedance waveguide 87 across the long dimension thereof. This bar is orthogonal to the electric field lines of the dominant mode propagated by the circular window, i.e., the T₁₁ mode. In the window assembly undesired resonant modes which have electric field lines that have components tangent to the bar 95 will be perturbed and thereby displaced in frequency by the bar 95. Many undesired resonant modes will be perturbed by this bar 95 and particularly the modes similar to the T₁₁₁ mode in round waveguide whose electric field is orthogonal to the electric field of the dominant T₁₁₁ mode. Preferably the bar 95 is positioned as near to the center of the window 81 as the bar 95 is visible but the bar 95 anywhere in the region of the window to be effective. In the preferred embodiment of the present invention the bar 95 is positioned in the waveguide section 87 outside the vacuum envelope of the tube so that it can be adjusted or plotted with material without effecting the vacuum within the tube. Also, the bar 95 could take the form of a wide septum 110 extending in the direction of wave propagation in waveguide section 87 as shown in FIG. 10.

A window assembly 22 constructed in the manner shown in FIGS. 7 and 8 will pass high powers over a 36% mode-free frequency band centered on a frequency of 865 mc.

Instead of the bar 95 being a metallic conductor it could be made of lossy material or coated with lossy material such as Kanthal to attenuate rather than to perturb undesired modes. Such attenuation means could also be positioned elsewhere in the path of the electric currents of undesired modes so as not to attenuate the currents of the desired mode.

This mode suppression means could also take other forms such as metallic wires, strips, or a layer of metal particles 95' positioned directly on or plated on the window 81' as shown in FIG. 9. Such mode suppression means would also serve the purpose of conducting away from the window surface charges which might have a
tendency to puncture the window. Also, the mode suppression means could take the form of attenuation means such as lossy strips (not shown) positioned so as to absorb wall currents of undesired modes or coupling means such as slots 97 (see FIG. 9) to couple the energy of undesired modes out of the region of the waveguide window. The attenuation and coupling means should be positioned so as to reduce the power in the desired dominant mode as little as possible.

The window assembly described above provides several advantages over prior art high power, broadband, circular waveguide windows of this general type constructed according to the teachings of the U.S. Patent 2,958,834. First of all, certain waveguide resonant modes can be perturbed or attenuated by mode suppression means in the form of electric conductors or attenuators positioned orthogonal to the electric field lines of the dominant mode. Secondly, in the present invention the reduction of the diameter of the outermost window 81 below the length of the diagonal of the rectangular waveguide shifts the frequency of certain resonant modes in the window assembly. A typical resonant mode shifted in frequency in this manner is the mode similar to the TE_{01} mode in a circular cylindrical resonator. By proper selection of waveguide window diameter this mode can be shifted out of the frequency band of interest.

In the structure according to the present invention wherein the diameter of the circular waveguide window 81 is less than the length of the diagonal of the rectangular waveguide 21, a pair of capacitive bars 101 and 102 are provided along the long side of the waveguide 21 and are machined in the output waveguide flange 89 at the junctions between the waveguide 21 and the flange 89 and the high impedance waveguides 87 and 88, respectively, to provide the net capacitive discontinuity as taught in U.S. Patent 2,958,834 referred to above. Certain aspects of disposing a plurality of orthogonal couplings on a dielectric window as disclosed herein are claimed in our continuation (divisional type) application U.S. Ser. No. 627,127, filed Mar. 30, 1967, of the subject application which is assigned to the same assignee as the present invention.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. High frequency tube apparatus including, (a) means for producing and directing a beam of charged particles over a predetermined path longitudinally of the tube, (b) means for collecting the beam at the terminating end of the beam path, (c) means spatially disposed apart along said beam path for producing successive electromagnetic interaction with said beam and for extracting high frequency energy from said beam, and (d) a metallic envelope disposed about the beam path forming an axially elongated vacuum-tight envelope for said device, said envelope including a plurality of cup shaped members disposed about the beam path; said cup shaped members each having an outwardly directed flange on the one end thereof and an inwardly directed flange forming an aperture base for each of said cup shaped members at the other end thereof, at least a plurality of said cup shaped members being arranged in pairs with the bases of the cups joined together to form a given pair, the one cup shaped member of each of said pairs being axially longer than the other cup shaped member of said pair, the longer cup member forming a resonant cavity for said device, and

2. A tuner mechanism for accurately adjusting the position of a movable tuner means mounted on a flexible wall of a cavity resonator comprising, in combination (a) an externally threaded tuner drive screw, (b) a hollow cylindrical tuner bearing member provided with a threaded exterior surface thereof for engagement with said tuner drive screw, (c) tuner support means for supporting said tuner drive screw and said bearing member, said support means adapted to be supported on said cavity resonator and to retain said tuning screw against rectilinear motion, and (d) means for securing and locking said bearing member to said flexible wall including threaded means for securing said bearing member to said flexible wall, a deformable member slideable in a recessed guide for said. In one embodiment, said flexible wall is made of flame resistant material and said tuner member is lockable to said flexible wall such that a fluid tight seal is created between said tuner member and said flexible wall.

3. A fluid cooled tuner mechanism for accurately adjusting the position of a movable tuner means of a cavity resonator comprising, in combination, (a) a flexible metallic bellows adapted to mount said tuner means; (b) a hollow cylindrical bellows support cup adapted to support therein said bellows through a wall of said cavity resonator; (c) a cup-shaped tuner supporting means provided with a hollow cylindrical bearing support portion extending radially inwardly toward the tube axis; (d) tuner actuating means positioned within said bearing support portion for providing motion to said bellows and thus said tuner means; (e) the opening within said cup shaped tuner support means outside said bearing support portion adapted to receive said bellows support cup and said bellows between said radially extending bearing support portion and the radial walls of said cup-shaped tuner support; and (f) said tuner support means and said bearing support portion thereof defining a chamber region therebetween;

4. High frequency tube apparatus including (a) means for producing and directing a beam of charged particles over a predetermined path longitudinally of the tube, (b) means for collecting the beam at the terminating end of the beam path, (c) means spatially disposed apart along said beam path for producing successive electromagnetic interaction with said beam and for extracting high frequency energy from said beam including, (1) a tunable output cavity resonator provided with an interaction gap therein and an output iris in a wall thereof for extracting radio frequency energy therefrom, (2) rectangular waveguide means communicating with said cavity resonator through said output iris, said rectangular waveguide having its width dimension tapered from a minimum at the iris to
a maximum outwardly thereof with the guide height maintained constant along said tapered section, said rectangular waveguide forming a step transformer beyond said tapered section, said step transformer section including a plurality of enlarged guide height dimensions such that said tapered section provides a frequency dependent impedance at the waveguide side of the output iris which is matched to an enlarged size rectangular waveguide via said step transformer.

5. A gas tight wave permeable window assembly dimensioned for passing wave energy therethrough over a certain passband of frequencies including,
(a) a waveguide transmission line,
(b) a resonant waveguide structure within said transmission line and which supports desired and undesired electromagnetic modes,
(c) an electromagnetic wave permeable dielectric window member sealed transversely of said waveguide transmission line, and
(d) selective mode suppression means positioned within said resonant waveguide structure in the immediate vicinity of said wave permeable dielectric window member for suppressing undesired modes within the passband of frequencies of said window member, which modes have maximum field strengths at said window.

6. A high frequency tube apparatus including
(a) means for producing and directing a beam of charged particles over a predetermined path longitudinally of the tube,
(b) means for collecting the beam at the terminating end of the beam path,
(c) means spatially disposed apart along said beam path for producing successive electromagnetic interaction with said beam and for extracting high frequency energy from said beam, and
(d) a vacuum tight envelope enclosing the beam path, said means for extracting wave energy from the beam including an electromagnetic wave permeable window positioned in a resonant structure which supports desired and undesired modes, and mode suppression means positioned orthogonal to the field lines of the desired mode whereby undesired modes will be suppressed within the frequency band of the tube apparatus, said mode suppression means being disposed in the immediate vicinity of said window for suppressing undesired resonant modes within the passband of said window which modes have maximum field strengths at said window.

7. The apparatus of claim 6 wherein the mode suppression means includes conduction means positioned orthogonally to the electric field lines of the desired mode of propagation through said wave permeable window assembly for suppressing undesired modes within the passband of frequencies of the window assembly.

8. The apparatus of claim 6 wherein the mode suppression means includes attenuating means for attenuating the currents of undesired modes without substantially attenuating currents of the desired mode of propagation through said wave permeable window assembly whereby undesired modes are suppressed within the passband of frequencies of the window assembly.

9. The apparatus of claim 6 wherein the mode suppression means includes coupling means for coupling energy out of undesired modes without coupling substantial energy out of the desired mode of propagation through said wave permeable window assembly whereby undesired modes are suppressed within the passband of frequencies of the window assembly.

10. High frequency tube apparatus comprising, in combination,
rents of undesired modes without substantially attenuating currents of the desired mode of propagation through said wave permeable window assembly whereby undesired modes are suppressed within the passband of frequencies of the window assembly.

15. High frequency tube apparatus including
(A) means for producing and directing a beam of charged particles over a predetermined path longitudinally of the tube;
(B) means for collecting the beam at the terminating end of the beam path;
(C) a vacuum tight envelope enclosing the beam path including
   (1) a plurality of metallic cup members, said members of said plurality of metallic cup members having bases on the one end thereof and having outwardly directed flanges,
   (2) at least a plurality of said cup members arranged in pairs with the bases of the individual cup members of each pair joined together,
   (3) an apertured disc member being adapted to support drift tube means,
   (4) adjacent cup members of adjacent pairs of cup members joined together at mating flanges on the other end thereof of said cup members with said disc member therebetween to form a rigid elongated tubular metallic envelope;
(D) means spatially disposed apart along with said beam path for producing successive electromagnetic interaction with said beam and for extracting high frequency energy from said beam including
   (1) tunable cavity resonator means including
      (a) a flexible cavity resonator wall,
      (b) a tuner member support within said cavity resonator supported on said wall,
      (c) a tuner actuating mechanism adapted to be supported on said tube apparatus, and
      (d) threaded means for screwing said tuner mechanism to said flexible cavity resonator for movement of said tuner member,
   (2) a tunable output cavity resonator provided with an output iris in a wall thereof for extracting radio frequency energy therefrom;
(3) output waveguide means communicating with said cavity resonator through said output iris and including
   (a) tapered wall portions having a frequency dependent characteristic which compensates for changes occurring due to tuning of the output cavity resonator in order to keep the gap impedance in the output cavity resonator constant over the tuning band of the tube,
   (b) high conduction means at said output iris for conducting heat from the walls surrounding said iris,
   (c) a circular pipe tight wave permeable window,
   (d) a first circular means forming a portion of a waveguide for supporting said window,
   (e) second and third semicircular and rectangular waveguiding means positioned on either side of said first means forming a portion of a waveguide,
   (f) a fourth tubular waveguiding means positioned between said second waveguiding means and said output cavity resonator,
   (g) said window having a diameter less that the greatest dimension of said fourth wave guiding means,
   (h) said first, second and third waveguiding means comprising a resonant structure which supports desired and undesired modes, and
   (i) mode suppression means positioned within said resonant waveguide structure for suppressing undesired modes within the pass band of frequencies of the window assembly.

16. The apparatus as defined in claim 1 wherein said drift tubes have a plurality of cooling channels extending along the length thereof and said cooling channels being adapted and arranged such that cooling fluid will flow bidirectionally along the length of said cooling channels.
17. A waveguide waist structure including a section of circular waveguide and means for establishing a broad band, strong hermetic seal across said section of circular waveguide, said window structure further comprising, a disc of dielectric material disposed transversely across said circular waveguide section and sealed along its periphery to said waveguide section, said disc being permeable to electromagnetic waves and impervious to fluids, a longitudinally extending septum extending within said circular waveguide along a diametral plane of said circular waveguide and said dielectric disc, said septum disposed in the immediate vicinity of said dielectric disc such that undesired modes in the pass band of said window are suppressed, means for coupling electromagnetic waves in the dominant TE_11 mode into said circular waveguide with the electric field of said waves normal to the broad surface of said septum.

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