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TUNABLE HIGH-FREQUENCY CAVITY RESONATOR

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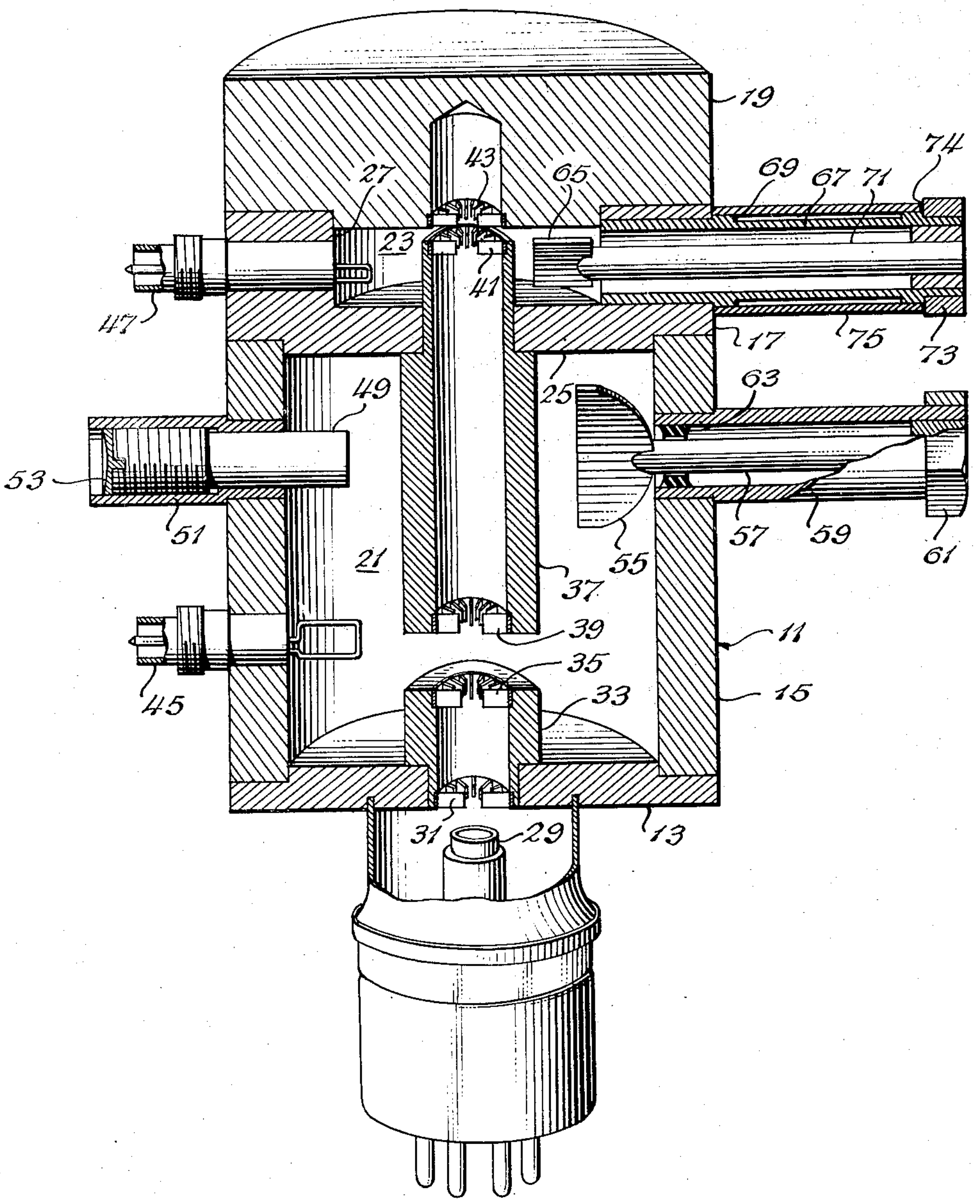

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TUNABLE HIGH-FREQUENCY CAVITY RESONATOR

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The present invention relates to high frequency apparatus, and more particularly, to high frequency electron discharge tube devices using cavity resonators, such as of the velocity-modulation type.

A common type of electron discharge tube comprises a tuned cavity resonator of which the operating frequency may be varied by adjusting the spacing or gap between a pair of electron-permeable grids mounted in alined openings formed in opposed wall portions of the resonator. For facilitating the adjustment of the gap, one or more of the resonator walls are made flexible. This feature is often very desirable especially when the tube is employed in frequency modulation applications or in other applications requiring wide frequency variation. However, for uses wherein a stable fixed frequency of operation is desired, variable grid spacing and/or other alterations in the size or shape of the cavity resonator are preferably avoided and, to this end, the cavity resonator is formed of rigid walls and special precautions are taken to maintain the grids a fixed distance apart. Such tubes may be referred to as "fixed-tuned" tubes.

It has been found that practical difficulties are encountered in fabricating fixed-tuned cavity resonator electron discharge tubes, especially with regard to the construction of a cavity resonator of predetermined dimensions and the maintenance of the spacing of the resonator grids a predetermined fixed distance apart. To overcome relatively large discrepancies introduced in either or both of these specifications, or to provide coarse preset tuning of the resonator, an adjustable plunger is introduced into the resonator thereby reducing the volume of the enclosed resonator space by an amount corresponding to a frequency shift which adjusts the resonator frequency at or near the desired operating frequency. For trim tuning or fine frequency adjustment, a substantially flat paddle or vane is mounted within the resonator; the spatial orientation of said paddle or vane with respect to the electromagnetic field configuration in the resonator serves to alter the frequency by the desired amount.

A principal object of the present invention, therefore, is to generally improve electron discharge tubes of the fixed-tuned preset cavity resonator type.

Heretofore, to produce translational and/or rotational motion of a body such as a tuning paddle supported in an evacuated cavity resonator, various expedients have been employed; for example, machined joints precision ground and

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packed with grease or diverse types of Sylphon bellows have been employed. The former means have been shown to be very unsatisfactory due to the contamination of the vacuum caused by the evaporation of the grease. Also, when the apparatus is used detached from the vacuum pump, it has been found that high vacua cannot be satisfactorily maintained. Sylphon bellows, aside from the fact that they add considerably to the cost of manufacture, suffer the disadvantage that they may be hard soldered only with great difficulty. Hard soldering, of course, is desirable because it is necessary, in the manufacture of the tube, to "bake out" the tube at a relatively high temperature so that the vacuum may be more readily maintained. Also, such bellows devices require special provision for maintaining as well as for varying their adjustments.

Accordingly, it is another object of the present invention to provide improved means for producing motion of a body such as a vane or paddle tuner supported in an evacuated cavity resonator.

Still another object of the present invention lies in the provision of novel mechanical arrangements for controllably varying the frequency of electron discharge tubes employing preset, fixed-tuned hollow resonator means.

Yet another object of the present invention is to provide novel and improved electron discharge tube apparatus having preset fixed-tuned hollow resonator means and means within said resonator means for controllably varying the operative frequency of said apparatus.

A further object of the invention is to provide coarse and fine tuning means for a fixed-tuned preset electron discharge tube of the cavity resonator type which are simple yet sturdy in construction, easily operated, and economical to produce.

In accordance with the present invention, it is proposed to provide, in the cavity resonators of an electron discharge tube of the fixed-tuned preset type, adjustable plunger means and/or adjustable paddle means for producing coarse and fine tuning respectively, said coarse and said fine tuning being preferably adjusted during fabrication of the tube, in various stages of the manufacture. As will appear, it is proposed to effect coarse tuning of the resonator by means of the adjustable plunger while the tube is yet in non-evacuated condition and, having arrived at approximately the desired frequency condition, to fixedly seal the plunger in position. Then, after the tube has been sealed off completely and evacuated, trim adjustment of the frequency to the precise desired frequency condition is made by means of the paddle tuner.

A feature of the present invention, therefore, lies in the provision of an adjustable mounting for a tuning or other adjustable element for use in an evacuated cavity resonator, said mounting including an inelastically deformable housing mounted on the resonator wall and cooperable with the tuning element by means of a rod coaxially supported within the housing and connected to the tuning element, whereby, upon axial torsional deformation of said housing, controlled axial rotation of the tuning element is obtained, while the housing is rigid enough to maintain the adjustment without further apparatus being necessary.

The invention in another of its aspects relates to novel features of the instrumentalities described herein for achieving the principal objects of the invention and to novel principles employed in those instrumentalities, whether or not these features and principles are used for the said principal objects or in the said field.

A further object of the invention is to provide improved apparatus and instrumentalities embodying novel features and principles, adapted for use in realizing the above objects and also adapted for use in other fields.

Other objects and advantages will become apparent from the specification taken in connection with the accompanying drawing wherein the single figure is a perspective view, partly in longitudinal cross-section, of a high frequency electron discharge tube embodying the novel features of the present invention.

Referring to the drawing, there is disclosed an electron discharge tube structure of the velocity-modulation type commonly known as a Klystron. Although the Klystron illustrated is of the frequency-multiplier variety, it will be understood that the embodiment of the present invention in a frequency-multiplier Klystron is merely for the purpose of illustration and description and is not to be considered as a limitation on the application and/or utility thereof, since the novel features herein may also be employed with equally satisfactory results in other varieties of Klystron tubes such as reflex oscillators, multiple cavity resonator oscillators, cascade amplifiers, oscillator-amplifiers, etc.

As shown in the drawing, the improved Klystron comprises a substantially cylindrical evacuated envelope 11 which may readily be fabricated of four interfitted sections comprising a centrally apertured circular bottom wall 13, a hollow open-ended cylindrical side wall portion 15, a circularly recessed, centrally apertured, disc-shaped member 17, and a circularly recessed cap member 19. The sections 13, 15, 17 and 19 are all of equal outside diameter so that, when fitted together in coaxial arrangement, the assembly forms the envelope 11 having a smooth outer peripheral surface and enclosing a pair of coaxially aligned cylindrical cavity resonators 21 and 23.

The bottom wall 13 and the proximate surface 25 of disc-shaped member 17 serve as the bottom and top walls, respectively, of the cylindrical resonator 21, while the cylindrical portion 15 provides the side wall enclosure of the resonator 21. The circularly recessed portion 27 of the disc-shaped member 17 together with the cap member 19 define resonator 23, which, it will be noted, is both shorter in length and smaller in diameter than resonator 21. The relative dimensions of the cavity resonators 21, 23 are preselected in accordance with the desired operating frequency and frequency multiplication ratio, as will appear.

It will be observed that the chambers 21 and 23 are each formed with relatively thick rigid metallic walls for the purpose of minimizing undesirable dimensional changes in the chambers caused by fluctuation in operating and/or ambient temperature conditions. It has been found that by making the chamber walls of thick metallic material, radiation of heat is enhanced and unwanted temperature gradients are substantially reduced, so that frequency drift due to change in size of the resonator walls is minimized. If desired, the walls may conveniently be provided with interconnected longitudinally extending ducts through which water or other suitable coolants may be circulated to aid in the removal of heat and thereby maintain a substantially uniform temperature condition.

As a supply of free electrons, there is provided a cathode 29 of any suitable conventional type which may include conventional focussing and/or control electrodes. Adjacent to cathode 29 is an electron-permeable grid 31 which is adapted to be maintained at a suitable positive potential relative to the cathode for the purpose of accelerating the electrons from cathode 29 to form an electron stream projected through grid 31.

Supported in the central aperture of bottom wall 13 and projecting coaxially within resonator 21 is a tubular reentrant post 33 which at one end is conductively connected to and supports grid 31 and which, at the other end, supports a similar grid 35. Supported in the central aperture of the disc-shaped member 17 and projecting, in part, within resonator 21 and, in part, within resonator 23 is a second tubular reentrant post 37. Grids 39, 41, similar to grids 31 and 35, are conductively connected to and supported in the end portions of reentrant post 37 located in resonators 21 and 23, respectively. Grid 39 is closely spaced from and parallel to grid 35, thereby providing a buncher or input gap therebetween while grid 41 is closely spaced from and parallel to a similar grid 43 supported in the mouth of the circular recess in cap member 19; said grids 41 and 43 forming a catcher or output gap therebetween. The interior of post 37 provides a substantially field-free drift space defining a path for the electron stream.

The theory and mode of operation of frequency-multiplier Klystrons of the general type herein disclosed is fully described in United States Letters Patent No. 2,281,935 granted May 5, 1942, to R. H. Varian and W. W. Hansen. As explained in the patent, the cathode 29 is normally maintained at a high negative potential with respect to grid 31 and the metallic envelope 11, which is grounded. Thus, electrons from the cathode 29 are formed into a beam which is projected axially of the evacuated envelope through the entrance grid 35 of resonator 21 which acts to provide a variable electron velocity along the beam. The variable-velocity electrons traverse the drift space and become bunched. Thereupon, the bunched electrons excite resonator 23 to oscillation by passage through the grids 41, 43 thereof. After passing through the exit grid 43 of resonator 23, the electrons impinge upon cap member 19 or any other suitable type of electron-collecting means.

Buncher resonator 21 is tuned to the fundamental frequency while the catcher resonator 23 is tuned to the desired harmonic output frequency. In operation, resonator 23 may be energized from any suitable source of ultra-high frequency energy by way of the coaxial line terminal 45. Harmonic frequency energy may be extracted from resonator 23 by terminal 47. For further details of the operation of the tube, reference may be had to the above-mentioned Patent No. 2,281,935.

As mentioned hereinbefore, the illustrated frequency-multiplier tube is intended for operation at fixed frequencies and for this reason the size and/or the shape of the resonators, as well as the lengths of the gaps formed between grids 35, 39 and 41, 43 are made invariant. However, in the manufacture of such tubes, slight discrepancies in resonator dimensions are found which seriously alter the desired frequency relationship. In accordance with the present invention, therefore, an adjustable plunger 49 is threaded into an internally threaded adapter 51 which, in turn, is suitably vacuum sealed in or formed integrally with the wall 15 of resonator 21. Axial adjustment of plunger 49 is made, prior to the final sealing and evacuation of the tube, to more or less roughly compensate for deviation of the resonator dimensions from the desired value. Thereupon the tube may be sealed off and evacuated and the positional adjustment of plunger 49 is secured as by capping the plunger 49 within the adapter 51 by soldering as at 53 or other suitable vacuumtight sealing.

After sealing and evacuating the tube, trim tuning or fine adjustment of the buncher resonator frequency is accomplished by means of a substantially flat vane or paddle 55 supported on one end of a rod 57 which is coaxially mounted in and rigidly secured at its other end to a tubular member or housing 59 by means of a nut 61. The tubular member 59 is formed of a material such as copper which may be readily inelastically deformed, and vacuum-sealed into the wall 15 at an opening formed therein, as by brazing or other equivalent means.

It has been found that axial rotational displacement of paddle 55 may be effected by applying torque to nut 61 and inelastically torsionally deforming the tubular member 59. Any convenient wrench or similar tool (not shown) may be employed at nut 61 for the purpose. Rotation of paddle 55 by as much as 90° may be had without injurious effects, although wide angle displacements are seldom required. If necessary, multiple angular adjustments in alternately opposite senses may be made.

To prevent axial bending of rod 57 and consequent translational movement of paddle 55 during twisting of tubular member 59, a reinforcing member or bead 63 of suitable dielectric material is mounted in the neck portion of tubular member 59. Reinforcing member or bead 63 has an axial hole formed therein through which rod 57 freely passes and thus serves as a bearing about which rod 57 may be rotated.

Other means for preventing bending of the paddle-supporting rod are shown applied to similar paddle tuner 65 in resonator 23. In this form, a tubular inelastically deformable member 67 is vacuum-sealed into disc-shaped member 17 at an aperture formed in the side wall thereof, and communicates with the interior of resonator 23. Member 67 is provided with a radially extending flange 69 which abuts the outer peripheral surface of member 17. Support rod 71 is rigid at one end with paddle 65 and at the other end with nut 73 which, in turn, is fixedly secured to the free end of tubular member 67. Axial bending of the rod 71 and consequent arcuate displacement of paddle 65 is prevented by means of a reinforcing member having the form of a cylindrical bearing jacket 75 which is coaxially fitted around the tube 67 and radially spaced therefrom by flange 69 and an annular shoulder 74 formed on nut 73, so that the tube 67 may be freely inelastically torsionally deformed by the application of turning moment thereto by means of a wrench or other suitable tool applied at nut 73.

It will be understood that, if desired, the bead 63 disclosed in the mounting of paddle 55 may also be used with this form of paddle mounting illustrated with paddle 65. Or, the jacket 75 arrangement may be employed in the mounting of paddle 55 as an additional safeguard against bending of rod 57.

It will be clear that an adjustable plunger, similar to the plunger 49 in resonator 21, may be provided for resonator 23, if coarse frequency adjustment is desired during fabrication of the tube. The omission herein of such a plunger from resonator 23 is for the purpose of simplifying the drawing and the description.

There has thus been disclosed and described a new and improved type of fixed-tuned preset electron discharge tube apparatus having cavity resonators. The frequencies of the resonators are preliminarily adjusted, during the manufacture of the tube, by means of an adjustable tuning plunger which, after adjustment, is sealed into position simultaneously with the final sealing of the remainder of the apparatus. Thereafter, the operating frequencies of the resonators are precisely adjusted by means of a novel force and motion transmitting mountings for paddle or vane types of tuner located within the evacuated resonators whereby controlled axial rotational displacement of the paddle or vane is obtained by inelastic axial torsional deformation of the mounting, without disturbing the evacuated condition of the resonator.

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. A tunable high frequency cavity resonator having an inner surface of conducting material, a substantially inelastic deformable tubular member sealed in vacuum tight relation to a wall of said resonator and extending outwardly from said resonator, a rod positioned within said tubular member and fixedly supported in vacuum-tight relation thereto adjacent the end of said rod remote from said resonator, a tuning member disposed within said resonator and supported on said rod, said rod and said tubular member being radially spaced apart to prevent contact therebetween upon torsional deformation of said tubular member, said rod serving to position said tuning member and to impart rotation thereto, said tuning member having unobstructed turning motion within said resonator when torsional deformation of said tubular member occurs upon the application of a turning torque at the outer end portion of said tubular member, and a reinforcing member carried by said deformable tubular member positioned to prevent

lateral displacement of said tuning member when a force applied to said deformable tubular member tends to laterally bend the same.

2. A tunable high frequency cavity resonator having an inner surface of conducting material, a substantially inelastic deformable tubular member sealed in vacuum tight relation to a wall of said resonator and extending outwardly from said resonator, a rod positioned within said tubular member and fixedly supported in vacuumtight relation thereto adjacent the end of said rod remote from said resonator, a tuning member disposed within said resonator and supported on said rod, said rod and said tubular member being radially spaced apart to prevent contact therebetween upon torsional deformation of said tubular member, said rod serving to position said tuning member and to impart rotation thereto, said tuning member having unobstructed turning motion within said resonator when torsional deformation of said tubular member occurs upon the application of a turning torque at the outer end portion of said tubular member, and a substantially inflexible jacket fixed against lateral movement adjacent said cavity resonator and

surrounding said tubular member, said jacket engaging said tubular member adjacent its end remote from said resonator, whereby axial bending of said rod and lateral displacement of said tuning member is prevented when a force applied to said tubular member tends to laterally bend the same.

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