

Aug. 30, 1960

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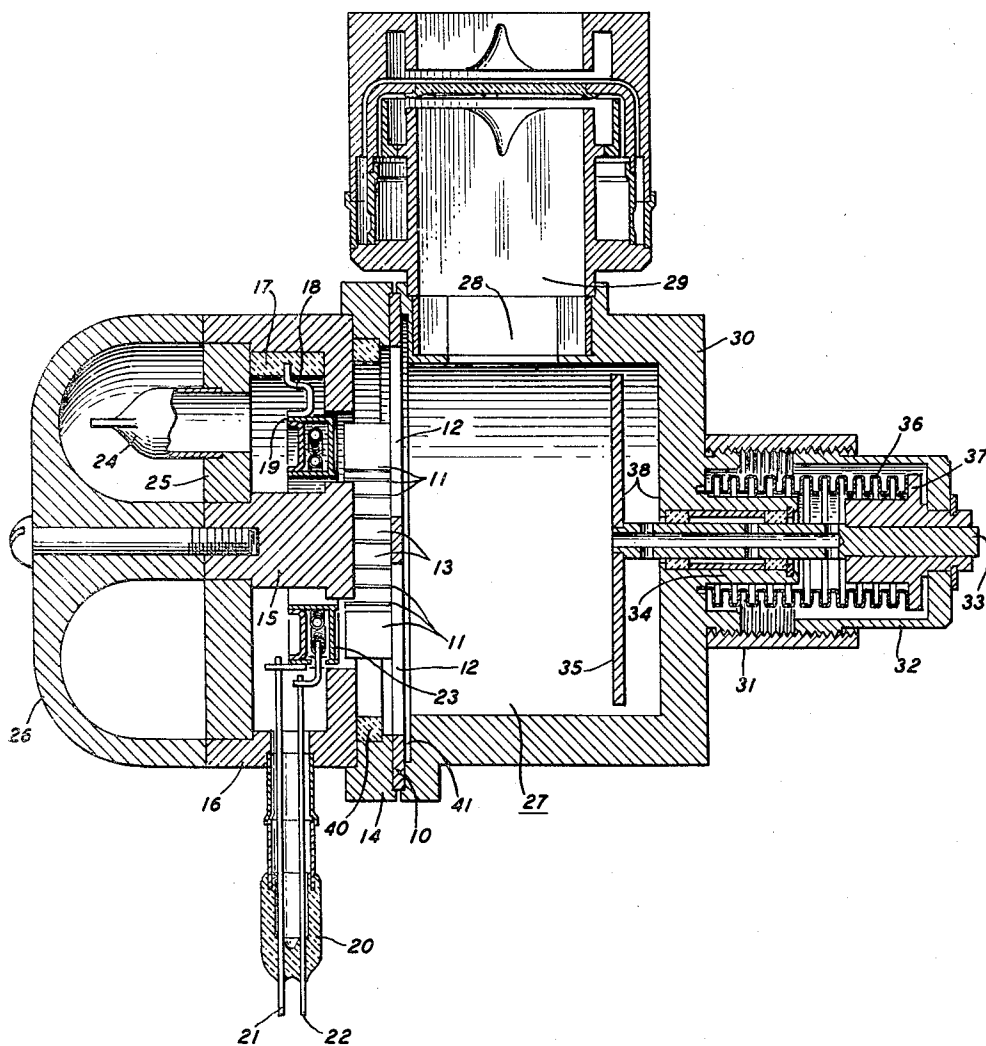
2,951,182

MAGNETRON

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2 Sheets-Sheet 1

FIG. 1



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2 Sheets-Sheet 2

FIG. 2

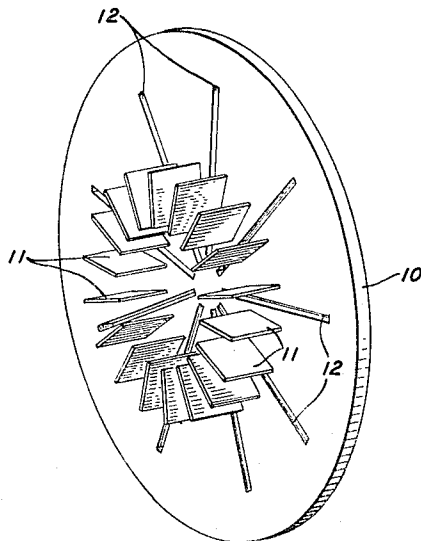
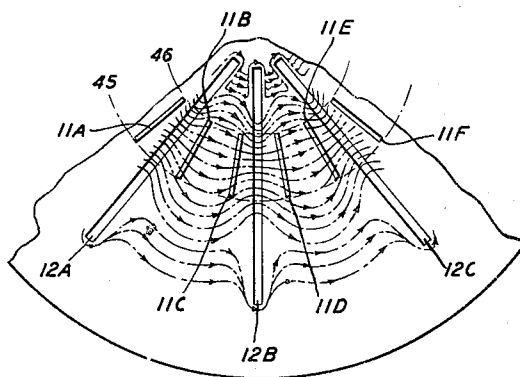


FIG. 3



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1

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MAGNETRON

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9 Claims. (Cl. 315—39.53)

This invention relates to electron discharge devices, and more particularly, to such devices of the magnetron type.

In the patent of R. J. Collier and J. Feinstein, No. 2,854,603, issued Sept. 30, 1958, there is disclosed a unique coaxial magnetron structure which comprises an inner and outer resonant system. The inner resonant system includes a plurality of anode vanes which extend radially inward from a cylindrical wall member. These vanes form a circumferential array of inner cavity resonators and are designed to be approximately one-quarter wavelength long at the operating frequency, the reason for which will become apparent later on. Coupling between the two systems is accomplished by a circumferential array of axially spaced slots through the cylindrical wall member, which is common to the inner and outer resonant systems, these slots communicating with alternate ones of the anode cavity resonators. These slots are advantageously made to extend beyond the limits of the outer resonator and thereby permit suitable damping elements and chokes to be positioned in close proximity to the ends thereof for removing or suppressing any undesirable modes from the desired mode without noticeably affecting the latter mode of the outer cavity resonator. An additional choke is also positioned in the outer coaxial resonator for displacing the frequency of any TM modes that could possibly impair the operating characteristics of the device. A single tuning plunger is utilized to vary the dimensions of the outer cavity resonator and effectively tunes the magnetron mechanically over a substantially wide frequency range without impairing the resonant characteristics of the anode resonators in any way. The inner resonant system is designed to oscillate in the π mode, and in accordance with the principles taught in this copending application, is effectively locked into the TE_{011} mode of the outer coaxial cavity resonator.

Such a structural arrangement overcomes many disadvantages inherent in magnetrons of prior conventional design. More particularly, the coaxial magnetron arrangement permits the realization of substantial high frequency stability and efficiency simultaneously under varying input and load conditions. Since these objectives are not consistent, an inadequate compromise between efficiency and stability, dependent on the particular application required, has been necessitated heretofore with conventional magnetrons.

More particularly, the problem of high efficiency is basically resolved by making the product of circuit efficiency times electronic efficiency a maximum. However, while the circuit efficiency is highest in high impedance oscillators, electronic efficiency depends upon the RF voltage across the oscillator gaps or vanes and occurs at an RF voltage usually lower than that which is attainable with conventional magnetrons in operation. Thus, the problem of increasing the electronic efficiency is one of reducing the RF voltage for a given power out-

2

put. The RF voltage across the anode gaps or vanes can be reduced either by decreasing the oscillator impedance, namely, decreasing the ratio of inductance to capacitance, L/C of the resonant system, or by coupling the system heavily to the load so as to reduce the amount of stored energy. Increasing the loading of a magnetron usually increases its efficiency. However, heavy loading means closer coupling between the load and magnetron and this makes the magnetron more sensitive to load changes or in other words, it reduces the frequency stability. Disadvantageously, a high impedance oscillator also has less stability against load changes than one with a low impedance and it may easily break into oscillation in an undesired mode, such operation being referred to as moding.

The aforementioned coaxial magnetron appreciably solves these problems by requiring substantially lower RF voltages across the anode gaps, by enabling the load to be heavily coupled to the outer resonant system, remote from the inner system and by utilizing a relatively high Q coaxial outer cavity resonator which reduces power losses, requires a lower circuit impedance, and enables effective and efficient coupling to be realized between the two resonant systems without in any way destroying the symmetry of the resonators. Still higher values of efficiency and stability are attainable with two resonant systems coupled in a similar manner, but modified by the type of outer cavity resonator and arrangement of the coupling slots as will become apparent hereinafter.

Similarly, a structural arrangement as disclosed in the aforementioned patent substantially overcomes the problem of interfering modes without requiring straps. This is accomplished partly by the specific geometry of the inner and outer resonant systems and also by the manner in which the undesired modes of this type are effectively loaded. More particularly, since every degenerate mode of the inner resonant system which is capable of existing at the anode vanes must have a boundary condition compatible with a spurious TE mode of the outer cavity resonator, it is possible to load the coupled undesired mode resulting therefrom by placing damping elements in those regions of the outer cavity resonator where such modes experience a current maximum. Any TM modes that could possibly interfere are removed in frequency from the output frequency range of the device by chokes suitably placed.

The elimination of straps is a distinct advantage in that at very high frequencies, straps become quite small and mechanically difficult to incorporate into the magnetron anode structure. Moreover, the small spacing results in excessive copper loss, and, therefore, lower magnetron efficiency.

As recalled from the description of the above-mentioned coaxial magnetron, coupling between the two resonant systems therein is accomplished by slots communicating with only alternate ones of the inner cavity resonators. This type of coupling basically results in the inner system by itself acting as an unstrapped rising sun magnetron. Such a magnetron structure has been purposely designed heretofore by specifically altering the physical shape and size of adjacent resonators in an attempt to overcome the problem of moding without the necessity of straps. Disadvantageously, however, this type of structure has presented several inherent shortcomings of its own. One problem arises when such a magnetron is operating in the π mode of oscillation. Associated with this mode of oscillation is a net RF current circulating around the entire anode and having the same frequencies as the π mode. The RF currents in the large, or otherwise altered, resonators exceed those in the small

ones, and, since the large currents are always in the same direction around the anode a net circulating current results. This circulating current gives rise to a zero mode contamination which interferes strongly with the desired mode of oscillation if the magnetic field is such that the cyclotron frequency of the electrons is close to that of the magnetron. The coaxial magnetron removes rising sun modes of oscillation, referred to hereinafter as slot modes, since most of the energy giving rise to such modes is stored in the slots of such a structure, by positioning damping elements at the ends of these slots to absorb energy stored therein when the inner resonant structure oscillates in rising sun modes. These damping elements have been found to be effective in removing specific modes of rising sun oscillations, but they have not proven completely satisfactory in removing a plurality of such modes which may exist in such a system, mainly, because the respective frequencies of such modes vary over a considerably wide range.

It is an object of this invention to provide an improved magnetron.

More specifically it is an object of this invention to provide an improved magnetron having an external resonant cavity coupled to the resonant cavities of the anode structure to prevent moding.

It is a further object of this invention to provide a magnetron structure having an externally coupled cavity resonator wherein all of the slot energy of the coupling slots is forced into a single slot mode. Accordingly, it is an object of this invention to provide a magnetron structure having coupling slots wherein all of the slot or rising sun mode energy may be facily removed by a single damping element and thus prevented from interfering with proper operation of the magnetron.

These and other objects of this invention are attained in one specific illustrative embodiment wherein the magnetron comprises an inner and outer resonant system. The inner resonant system utilizes a circular end plate upon which is mounted a plurality of vanes which extend perpendicularly from the end plate and are radially disposed with respect to the axis thereof, thus forming a circular array of anode cavity resonators. As taught in the aforementioned patent, the anode vanes are arranged to be approximately one-quarter wavelength long at the frequency of the outer cavity resonator. This assures that the slots present a low impedance path to the currents of the desired mode of the outer cavity resonator whether it be oscillating at the same or a different frequency from that of the inner anode resonant system.

In accordance with one aspect of my invention, the outer resonant system is coupled to the anode resonant system by a circumferential array of radial slots extending through the circular end plate, the slots communicating with alternate ones of the anode cavity resonators. This particular slot arrangement results in all of the slots extending radially inwardly toward a common center, and in certain applications, it may be advantageous that they actually merge at the center of the circular end plate. Significantly and advantageously, these merging slots force the various phases of excitation normally present in the slots into one common or identical phase of excitation. In other words, these various phases of excitation or spurious uncoupled slot modes, which exist due to the rising sun characteristics of the inner resonant system, described in greater detail hereinafter, will be forced into one identical slot mode as they have a common point due to their radial arrangement. This greatly improves the stability of the magnetron since one specific slot mode can easily be removed by a suitably placed damping element, as taught in the aforementioned patent. In fact, this single slot mode in many cases will be so insignificant, in terms of energy with respect to the dominant mode of the outer system, that it need not even be damped out.

A high Q circular electric mode cavity is advantageously utilized as the outer resonant system. This assures that a minimum of stored energy will be lost and, thus, enables a higher circuit efficiency to be attained.

This resonator operates in the TE_{011} mode wherein the magnetic field is axial and the electric field is circumferential. Hence, the electric currents are circular and flow around the end plates, being maximum in the region defined by the width of the inner cavity resonator vanes. This affords a proper current relationship between the inner and outer systems which assures that the anode resonators will oscillate in the π mode. Such a coupling relationship also assures that the inner system will be locked into the desired mode of operation, namely, the TE_{011} mode in this particular application. Accordingly, this enables a high degree of stability to be realized without the necessity of strapping, and thus, power losses in the anode resonant system and distortion of the RF field due to strapping are eliminated.

The circular electric mode outer cavity resonator is also advantageous in that together with the novel arrangement of the coupling slots, the TE_{121} mode, normally present in the above-described coaxial magnetron, is substantially removed in frequency from the TE_{011} mode of the outer resonator. This eliminates the necessity for damping elements.

It is a feature of this invention that a magnetron comprise a plurality of anode vanes radially disposed on an end plate, coupling being provided between the anode resonators thus formed and an external resonant cavity by a plurality of radial slots extending in the end plate.

It is a further feature of this invention that the slot mode or rising sun mode energy stored in the slots be forced into a single mode by the radial arrangement of the coupling slots, whereby substantially all of the energy stored in the coupling slots may readily be damped by an appropriately placed damping element. In accordance with this feature of the invention, the amount of energy stored is considerably lessened by the radial coupling slot arrangement so that, in fact, damping of the stored energy may not be necessary in all instances.

It is another feature of this invention that the coupling slots between the anode cavity resonators and the output resonator be arranged so that the currents in these slots due to rising sun modes have a common point whereby they must have a common phase of excitation. Specifically, in accordance with this feature, in one embodiment of the invention the slots are arranged radially from a common axis and extend towards that common axis to force the energy in the slots into this common phase of excitation. In accordance with this feature of my invention, the circumference of the circle defining the inner ends of the merging radial slots should be advantageously not more than of the order of a quarter wavelength of the slot mode frequency to assure that this area common to energy stored in all the radial slots does not allow different phases of excitation but forces all the energy in the slots into a common phase of excitation.

A complete understanding of this invention and of these and other features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a sectional view of a magnetron illustrative of one specific embodiment of this invention;

Fig. 2 is a perspective view of the anode vanes and common wall end plate in the embodiment of Fig. 1; and

Fig. 3 is an enlarged side view of a portion of the common wall end plate showing current flow along the wall and into the slots in the embodiment of Fig. 1 for the dominant TE_{011} mode.

Referring now more particularly to the drawing, the specific illustrative embodiment of this invention depicted in Fig. 1 comprises a common wall circular end plate 10 having a plurality of vanes 11 which extend perpen-

dicularly therefrom and are radially disposed with respect to the axis thereof, as best seen in Fig. 2. Advantageously, these vanes 11 are approximately one-quarter wavelength long at the TE_{011} mode frequency range of oscillation in the outer system. The vanes 11 may be attached to the circular end plate 10 by brazing or other well known methods.

In accordance with an aspect of this invention, slots 12 extend through the circular end plate 10 and are disposed radially a substantial distance beyond the anode vanes on either side, communicating with alternate ones of the inner cavity resonators 13 defined between adjacent anode vanes 10, as is best seen in Fig. 2. Positioned adjacent the wall member 10 on one side is an annular support collar 14 which is notched to position rigidly the annular cathode pole piece structure comprising inner and outer members 15 and 16, respectively. Abutting the inner side of pole piece member 16 is a ceramic cathode support 17 from which is projected a U-shaped cathode support member 18, one end of which is fastened directly to one side of the annular cathode structure 19. Diametrically opposite the cathode support member 18 is a cathode stem 20 extending through the outer pole piece member 16. Stem 20 supports the two filament lead in wires 21 and 22 which are also utilized to support the cathode structure 19. Of course, additional supports may advantageously be utilized, and such supports may take the place of the filament lead in wires 21 and 22 now illustrated for that purpose. The annular cathode 19 has an emissive coating 23 on the side adjacent the anode vanes 11. An exhaust tubulation 24 extends through an annular nonmagnetic bridge 25 which encloses and affords a vacuum seal for the outer end of pole piece members 15 and 16. A suitable magnet 26, of magnetic material such as Alnico V, is attached to the inner and outer pole piece members 15 and 16, respectively.

On the side of the circular end plate 10 opposite the anode vanes 11 is a circular electric mode cavity resonator 27. This outer cavity resonator 27 is connected through a suitable transducer, such as an H-shaped transformer section 28, known in the art, to an output wave guide section 29 through which the energy of the magnetron is transmitted to external circuitry. The transformer section 28 is inserted through the side of outer wall 30 of the cavity resonator 27.

Attached to the outer wall 30 of cavity resonator 27 opposite the common wall end plate 10 is a tuning support sleeve 31. The cup-shaped tuning cap 32 follows a grooved path, axially along the inner periphery of support sleeve 31. A tuning shaft 33 extends through a sleeve 34 which also forms a part of the cavity resonator wall 30 into the outer cavity resonator 27 and supports a tuning disk 35. Advantageously, disk 35 can thereby effectively vary the dimensions of the outer cavity resonator 27 to tune the magnetron over a substantially wide frequency range with no metal-to-metal contacts between the inner and outer resonant systems being required. Further, not only is this type of tuning much more simplified than the conventional multipin tuning of the resonator bores themselves, but it also does not impair the resonant characteristics of the anode resonators. The siphon bellow 36 is attached between the outer resonator wall 30 and a yoke 37 which is secured to the tuning shaft 33 to maintain a vacuum within the magnetron. The back side of the tuning disk 35 and the wall of the cavity resonator directly adjacent the tuning disk 35 are both advantageously lined with Kovar coatings 38 to damp out back cavity resonances on motion of the tuning disk 35 axially into the cavity resonator 27.

As illustrated in Fig. 1, the inner radius of the annular support collar 14, to which the circular end plate 10 and outer pole piece member 16 are secured, is larger in diameter than is the inner diameter of the outer cavity resonator 27 defined by wall member 30. Similarly, the

slots 12 extend beyond the inner radius of the outer cavity resonator 27. This structural arrangement enables a lossy absorber ring 40, secured to both the outer pole piece member 16 and support collar 14, to be positioned beyond the radius of the outer resonator 27 for removing any undesired slot modes. In this region, neither the slots 12 nor the absorber ring 40 can communicate with or interfere with the TE_{011} mode of oscillation in outer resonator 27. Of course, this absorber ring would be equally effective if positioned in close proximity to the ends of the slots near the center of the circular end plate 10. This absorber ring 40 may be a carbonized ceramic such as alumina or a lossy ceramic such as barium titanate; however, other materials may be utilized with equal effectiveness. The significance of these slot modes will be considered in greater detail hereinafter when the rising sun characteristics of the anode system are considered.

As previously mentioned, in accordance with another aspect of this invention, the utilization of a circular electric mode cavity resonator 27 in conjunction with the particular coupling arrangement employed in this invention eliminates the necessity of considering compatible boundary conditions between the degenerate modes of the inner system and the TE_{121} and TM modes of oscillation of the outer system. More particularly, the specific geometry of the outer cavity resonator 27, together with the location of the coupling slots 12, removes the electric field configurations of the TE_{121} and TM modes of oscillation from coupling proximity with the degenerate modes of the inner cavity resonators 13. Further, by inserting tuning disk 35 into the outer cavity resonator 27, it effectively splits the TM mode of oscillations, which results in a greater frequency separation from the TE_{011} mode than if it were not present. A suitable choke positioned at the outer end of and formed by air gap 41, defined between the circular end plate 10 and the wall member 30 of outer cavity resonator 27, results in the TM mode being removed still further in frequency from the TE_{011} mode, as it is in this region where the TM modes have a current maximum.

In order to understand the operation of this invention, and the advantages derived therefrom, it is necessary to consider only two specific types of resonant systems that exist in the structure depicted in Fig. 1. These are first, the system comprised by the interaction of the outer circular electric mode cavity 27 with the inner cavity resonators 13, in accordance with the principles of operation of the invention described herein; and second, the system comprising a rising sun type of magnetron structure effectively established when it is considered that the coupling slots 12 communicating with alternate ones of the inner cavity resonators 13 result in adjacent cavity resonators which are different and alternate resonant cavities which are similar. This second system of operation will be considered in greater detail subsequently when the function of the absorber ring 40 and the specific arrangement of the coupling slots 12 are discussed.

Considering the inner and outer systems as a single composite system, there is one mode of operation for each system which results in compatible boundary conditions that are identical at the circular end plate 10, and which effectively locks the two systems together at the frequency of the fundamental mode of the outer cavity resonator 27. This compatible relationship exists when the inner cavity resonators 13 oscillate in the π mode and the outer resonator oscillates in the TE_{011} mode. The various electric and magnetic fields for these two modes and the manner of operation of the structure depicted in Fig. 1, which is illustrative of one embodiment of this invention, will now be described.

The outer circular electric mode cavity 27 is dimensioned such that maximum energy storage occurs in the TE_{011} mode which is a symmetric mode in which the magnetic field lines are axial between the end plates and

radial along the outer resonator end plate. The electric field lines are entirely circumferential, electric currents flowing circumferentially around the circular end plate 10 of the cavity resonator 27 and being maximum in the region coinciding with the width of the anode vanes 11.

The inner resonator system oscillating in the π mode establishes a magnetic field which traverses through the anode vanes radially and parallel with respect to the end plate 10, being of opposite direction in adjacent resonators 13 as required for the π mode of oscillation. The direction of the magnetic field in the directly coupled cavity resonators is in the same direction as the radially extending magnetic field along the circular end plate 10.

The resonant system defined by the resonators 13 alone may be considered as the usual untrapped magnetron system capable of oscillating in both the π mode and the various degenerate modes in close proximity thereto. However, because of the unique structural arrangement of the device depicted in Fig. 1, these spurious TE modes will be so far removed in frequency from the desired TE₀₁₁ mode, as well as not having an electric field configuration which is compatible with any degenerate modes arising out of the inner cavity resonators 13 that they need not be considered as modes giving rise to interference with the TE₀₁₁ mode of oscillation with which the instant invention is particularly concerned.

The TM modes, of course, cannot couple into the inner resonators 13 as they do not have either radial or circular components across the end plate 10, thus they cannot be electronically excited by the inner resonators 13. If desired, however, the TM₁₁ mode in particular can be removed even further in frequency from the TE₀₁₁ mode by placing a quarter wave choke between the end plate 10 and the outer cavity resonator wall 27, which is where the TM₁₁ currents are a maximum. This choke may actually comprise the air gap 41, such as depicted in Fig. 1.

In structures in accordance with this invention, current flows circularly around the common wall end plate 10 and arrives at a slot 12 perpendicular to the direction of the slot. The current sees what is essentially a short transmission line terminated in an open impedance; this characteristic is established by two adjacent anode vanes 11 terminated by the anode interaction gap adjacent the annular magnetron cathode. Advantageously, by making these vanes approximately one-quarter wavelength long in the range of frequencies of the current flowing along the end plate 10, the high impedance termination at the inner end of the anode vanes, namely, across the interaction gap, is thus reflected back to the slot 12 as a very low impedance. Accordingly, the current flows into the directly coupled cavity resonators 13 and follows a substantially closed loop defined by the boundaries of adjacent anode vanes connected by the interaction gap, this gap affording what is actually a capacitance through which the current flows. Upon the current traversing the periphery of a directly coupled resonator, the current proceeds in a circular path around the end plate 10 until the next slot 12 is reached where the process is repeated.

Since relatively high currents are supplied from the outer cavity resonator 27 to the ends of the anode vanes 11, sufficiently high voltages appear at the inner ends of the anode vanes 11 because of the quarter wave transformation involved. As only alternate ones of the inner cavity resonators 13 are directly coupled to the outer system, relatively high RF voltages appear across the inner ends of only alternate pairs of anode vanes 11 defined by coupling slots 12 therebetween. Voltages appearing across the other alternate pairs of anode vanes 11 are established by mutual inductances and characterized by being 180 degrees out of phase with the voltages appearing across adjacent pairs of anode vanes. It is such a condition that is necessary for sustaining the π mode of oscillation in the inner resonant system. It should be emphasized, however, that the relatively high

RF voltage appearing across the anode vanes by direct coupling with the outer system is substantially less than normally required in magnetrons of the prior art in order to sustain oscillations in the inner system.

Since no other modes of oscillation present compatible boundary conditions between the two systems, the π mode of oscillation of the inner system is locked into the TE₀₁₁ mode of the outer system in energy transfer relation.

To secure optimum coupling it is desirable that a maximum of the current flowing circularly around the end plate 10 flow into the anode resonator 13 directly coupled to the outer system by slots 12. As previously noted, slots 12 are essentially open circuits and, therefore, present high impedance paths for the currents flowing circularly around the end plate 10. However, in a region along the slots 12 defined by the width of the anode vanes 11, a low impedance is seen by the current due to the one-quarter wave impedance transformation caused by the vanes themselves. This can best be seen in Fig. 3 which is a detail in section of a portion of the circular end plate 10, anode vanes 11A through 11F, and three slots 12A, 12B and 12C being depicted. Lines 45 and 46 represent the region of slots 12 defined by the width of anode vanes 11.

From Fig. 3 it is seen that the current upon approaching a slot 12 attempts to follow the lowest impedance path; namely, that path defined by the region intermediate lines 45 and 46. This results in a substantial amount of the current being concentrated in that portion of the slot defined by the width of the anode vanes 11. The various paths illustrative of current flow around the circular end plate 10 are depicted by a plurality of lines with arrows indicating direction.

It is also seen from Fig. 3 that there is a point along slots 12 radially removed from lines 45 and 46 at which the current sees two equal impedance paths; namely, the impedance path converging within the area defined by lines 45 and 46 and the impedance path around the outer end of slots 12. In order to reduce this end flow of current to a minimum, the slots 12 are extended a considerable distance on either side of lines 45 and 46, as best seen in Fig. 3. Advantageously, the slots 12 are actually extended beyond the periphery of the outer cavity resonator 27 so as to enable dissipative or selective damping means to be positioned in close proximity thereto for selectively damping out any slot mode that may arise in the inner system because of rising sun characteristics. Further, in accordance with my present invention, the slots 12 extend inwardly beyond the inner edges of the anode vanes 11 so that the common point or area within the slots is sufficiently small so that only a single phase of excitation of the slot modes can be sustained. This common area comprises the circle defined by the inner ends of the radial slots 12 and in this embodiment that circle comprises the portion of the end plate 10 adjacent the common axis. In other embodiments wherein the slots merge at the common axis, that circle would comprise the common axial aperture. In either case, the circumference of that circle is advantageously of the order of less than a quarter wavelength of the slot mode frequency.

To enable a better and more complete understanding of the operation of my invention, let us consider the second basic resonant system; namely, the inner cavity resonators operating independently of the outer system. This inner system alone gives rise to a rising sun type of structure inasmuch as adjacent resonators 13 are physically different by the presence or absence of a coupling slot 12. It has been found that the rising sun frequencies of oscillation are considerably removed from the frequency range of both the π mode of the inner system and the TE₀₁₁ mode of the outer system. Significantly, the rising sun system is independent of the outer cavity resonant system and, thus, cannot be electronically excited by the latter. It has been found, however, that

normally the inner system will oscillate as a rising sun structure at both frequencies and voltages below those of either the π mode or TE_{011} mode.

Advantageously, in accordance with an aspect of this invention, the radially extending slots, by approaching each other near the center of the circular end plate 10, will force the various phases of excitation, or rising sun slot modes, existing therein to merge into one specific slot mode. Specifically, the slots should be arranged at their inner ends so that the circumference of the common area at the center of the end plate is not more than of the order of a quarter wavelength at the slot mode frequency. This greatly reduces the difficulty previously encountered in effectively damping out completely a plurality of such spurious modes. The rising sun mode of oscillation that may remain is effectively damped out by the dissipative ring 40.

It is to be understood that the specific embodiment described is merely illustrative of the general principles of this invention. Various other arrangements and physical dimensions may be devised in the light of this disclosure by one skilled in the art without departing from the spirit and scope of this invention. For example, in the described embodiment of this invention, coupling slots 12 have been illustrated as relatively long and narrow. However, the physical shape and size of these slots 12 may be altered to optimize particular characteristics as to conditions and frequencies in a particular embodiment without departing from the principles of this invention. Other changes will readily be apparent to one skilled in the art.

What is claimed is:

1. A magnetron comprising a flat circular end plate, a plurality of anode vanes positioned on said end plate in a circular array and defining a plurality of cavity resonators, cathode means positioned adjacent the ends of said anode vanes remote from said end plate, means including said end plate defining an external cavity resonator, and means coupling said external cavity resonator to certain of said anode cavity resonators, said coupling means including a plurality of individual slots extending through said end plate, said slots being radial, coaxial with said anode vanes, and extending beyond the edges of said anode vanes whereby storage of energy in said slots is forced to be in a common slot mode.

2. A magnetron in accordance with claim 1 further comprising damping means positioned in said slots for damping said common slot mode energy.

3. A magnetron comprising a flat end plate, a plurality of anode vanes radially positioned on said end plate and defining a circular array of anode cavity resonators, an annular cathode adjacent said anode vanes, means for establishing a magnetic field between said anode vanes and said cathode, means including said end plate forming an external cavity resonator, and means for coupling said external cavity resonator to said anode cavity resonators, said coupling means comprising a plurality of radial slots extending through said end plate connecting alternate ones of said anode cavity resonators to said external cavity resonator, said slots extending beyond the edges of said anode vanes and forcing energy storage in said slots to be in a single slot mode.

4. A magnetron in accordance with claim 3 wherein dissipative means are positioned in close proximity to the ends of said coupling slots, said dissipative means damping out said energy stored in said slots in said single slot mode due to rising sun oscillations existing in said anode cavity resonators.

5. A magnetron comprising a flat circular end plate, a plurality of vanes extending perpendicularly from said end plate and radially disposed with respect to the axis thereof forming a circular array of anode cavity resonators, an annular cathode positioned adjacent said anode vanes opposite said end plate and having a planar annular

emissive surface coinciding with the width of the ends of said vanes, means for establishing a magnetic focusing field which extends in a radial direction with respect to the axis of said annular cathode and intermediate the emissive surface of said cathode and the ends of said anode vanes, said means comprising an axially aligned inner pole piece member and an axially aligned outer pole piece member, the two members together forming an annular pole piece structure, means including said end plate forming an external circular electric TE_{011} mode cavity resonator, means for coupling said external cavity resonator to said anode cavity resonators, said last mentioned means comprising a plurality of radial slots extending through said end plate communicating with alternate ones of the anode cavity resonators in said array, said slots extending beyond the edges of said vanes, damping means positioned adjacent the ends of said coupling slots for selectively absorbing undesired modes of oscillation which cause energy storage in said slots, means positioned in said outer cavity resonator for removing in frequency undesired TM modes of oscillation existing therein, and means for varying the dimensions of said external cavity resonator to tune said magnetron, said last mentioned means comprising a single tuning plunger projecting into said cavity in an axial direction.

6. A magnetron comprising a flat end plate, a plurality of anode vanes positioned on said end plate in a circular array and defining a plurality of cavity resonators, cathode means positioned adjacent the ends of said anode vanes remote from said end plate, means including said end plate defining an external circular electric mode cavity resonator, and means coupling said external cavity resonator to certain of said anode cavity resonators, said coupling means including slots extending through said end plate, said slots being radial, coaxial with said anode vanes, and extending inwardly past the edges of the anode vanes toward the common axis sufficiently so that storage of energy in said slots is forced to be in a common slot mode.

7. A magnetron in accordance with claim 6 wherein said slots approach said common axis sufficiently so that the circumference of a circle defining the inner ends of said slots is less than of the order of one-quarter wavelength of the common slot mode frequency.

8. A magnetron comprising a flat end plate, a plurality of anode vanes radially positioned on said end plate and defining a circular array of anode cavity resonators, an annular cathode adjacent said anode vanes, means including said end plate forming an external circular mode cavity resonator, and means coupling said external cavity resonator to said anode cavity resonators, said coupling means comprising a plurality of radial slots extending through said end plate in alternate of said anode cavity resonators, said slots extending inwardly toward the common axis of said slots and said anode array sufficiently so that energy in all of said slots has a common point whereby said energy is forced into a common phase of excitation.

9. A magnetron in accordance with claim 8 wherein said common point comprises a circle defined by the inner ends of said slots, said circle having a circumference less than a one-quarter wavelength of the frequency of said common phase of excitation.

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