Jan. 28, 1958 J. FEINSTEIN 2,821,659

MAGNETRON

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FIG. 2

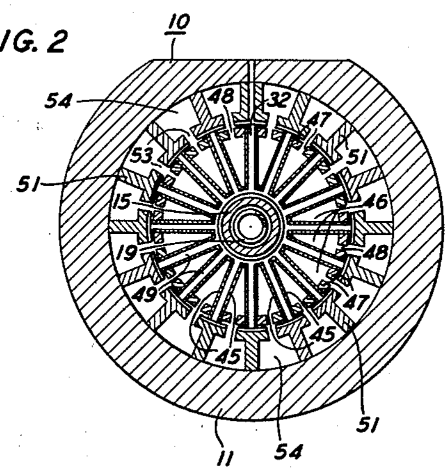


FIG. 1

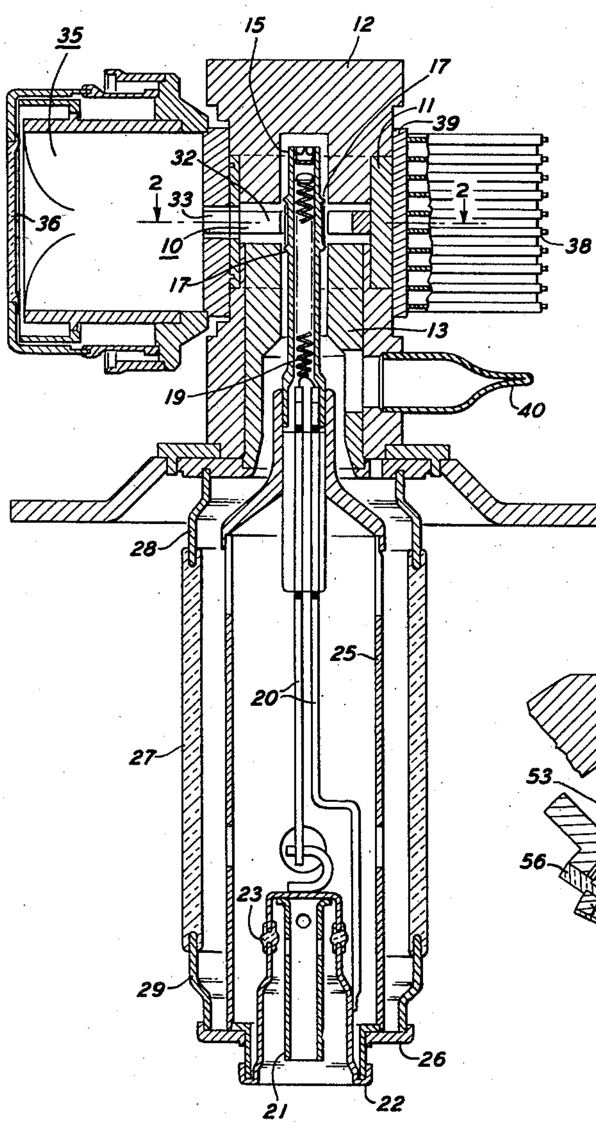
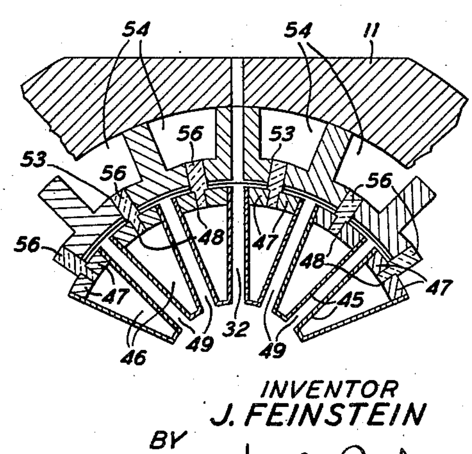


FIG. 3



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MAGNETRON

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This invention relates to electron discharge devices and more particularly to multicavity magnetrons.

When oscillations start to build up in a resonant circuit comprising a ring of cavity resonators, such as in a multicavity magnetron, competition exists between the various possible modes of oscillation. Generally it is desired to have oscillation occur in what is referred to as the π-mode. However, under various conditions the build-up of oscillation in a different mode may be preferred by the circuit; this build-up of oscillation in other than the desired π-mode of oscillation is referred to as moding. The usual approach to the moding problem has been two-fold: mode frequency separation and selective mode loading. The frequencies of the modes of the magnetron resonator system near that of the π-mode would ordinarily be closely grouped were not steps taken to separate them. Priorly mode separation has generally been accomplished by two methods. The first, and more common, has been to increase the coupling by conductive connections between the resonators and particularly by employing straps; this is generally referred to as "strapping." This increases the frequency separation by increasing the coupling between resonators. The second method has been to use cavities tuned alternately to different frequencies; this latter method has been employed in what is generally referred to as the "rising-sun" anode structure. This method increases the frequency separation by detuning the adjacent resonators relative to one another.

Further to prevent moding, selective loading of the degenerate or unwanted mode most likely to oscillate in place of the π-mode has also been employed. This mode is generally the one closest in frequency to the π-mode. Selective loading may be obtained by changes in the internal anode structure of the magnetron or by elements located external to the magnetron and particularly in the output wave guide connected to the magnetron.

These prior methods have not generally proven satisfactory at higher frequencies. Strapping is limited in the number of resonators that may be employed. Further the two approaches of frequency separation and mode loading are not independent of each other, the selective loading in fact tending to hinder the mode separation. At high frequencies this has been found to raise serious problems in prior structures.

It is a general object of this invention to provide improved anode structures for multicavity magnetrons.

Further objects of this invention include improving the frequency separation of the mode of oscillations of a magnetron, enabling improved operation of magnetrons at high frequencies, and preventing moding in magnetrons when operated at high frequencies.

As mentioned above, the mode separation in a magnetron can be varied as the coupling between adjacent resonant cavities is varied. In accordance with one aspect of this invention, optimum coupling between adjacent resonators is attained not by conductive connections,

such as straps, but by a capacitive coupling adjacent the inductive regions of the resonators.

In one specific illustrative embodiment of this invention a magnetron comprises a plurality of hollow anode segments mounted circumferentially around the central or cathode cavity. Advantageously the anode segments may be formed as hollow vanes as by the forming or bending of a metal strip. At the base of each vane are a pair of capacitance members extending inwardly toward each other and defining a small capacitive gap. The vanes may advantageously be supported from an outer anode rim by T-shaped members which provide the end closure for the resonator slots defined between adjacent anode segments. Two adjacent T-shaped members also define a capacitive gap, of slightly larger dimensions, directly adjacent, and electrically in parallel with the first gap. The two T-shaped members thus also enclose a hollow portion.

For the π-mode of oscillation, there is no potential across these capacitive gaps and therefore no π-mode energy is stored in these gaps. For other modes of oscillation, however, a potential difference does exist across the gaps and energy of these modes is stored; the optimum condition for mode separation is that one half of the energy of the unwanted modes is stored in the capacitance gaps, the other half being stored in the capacitance of the resonators itself.

In order to utilize the potential difference between these two points defining the capacitance gap at the base of each anode vane, it is necessary that this coupling capacitance not be shorted by the anode vane or segment itself. Accordingly, each anode segment is made hollow to serve as a choke and prevent the continuous conducting path of the anode segment providing an electrical short across the gap. As the area of the anode vane is limited, the choke defined by the hollow vane also is limited; accordingly, it is advisable to have the gap across the base of the anode vane small to have a high capacitance so that the choke section may be also quite small. The inductances of these choke sections should be sufficiently great that they have a negligible shunting effect on the capacitance gaps at the frequencies of the magnetron. Thus the high capacitance, low impedance gap is advantageously employed with the small choke section possible in the anode vane.

However, in accordance with another aspect of the invention, additional energy of the unwanted mode fields is stored in the capacitance gap defined between the ends of adjacent T-shaped sections supporting the anode vanes. As noted above, these second gaps are directly adjacent and in parallel with the primary gaps at the base of the anode vanes. A second choke section is also provided for these gaps; this choke section is advantageously defined by the hollow portion bounded by two adjacent T-shaped members and the outer supporting rim. In this case there is no limitation necessarily imposed on the area of this choke section, as the diameter of the outer rim and the length of the T-shaped members may be increased as desired. It is thus possible to have these secondary gaps of low capacitance values for the storage of the field energy of the unwanted modes.

As only the unwanted mode energy is stored in these gaps, loading of the unwanted modes can readily be attained, in accordance with another specific embodiment of this invention, by introducing a lossy dielectric into these gaps. This can be a material, such as barium titanate, which can introduce loss to reduce the Q of the unwanted modes. The insertion of a lossy dielectric material possessing a loss factor tangent θ in these capacitors has a first order effect of reducing the Q of the unwanted modes to $1/\tan\theta$. There is actually also a second order effect tending to reduce the mode separation, but this remains negligible until loss factors of the order unity are reached.

It is a feature of this invention that an anode for employment in a magnetron comprise a plurality of hollow anode segments having capacitance members at the base of the anode extending across the hollow portion and defining a capacitance gap.

It is a further feature of this invention that the anode segments be supported by conductive members defining a second capacitance gap directly adjacent and parallel to each of the first gaps, the conductive members also defining a hollow choke portion communicating with the second gap.

It is another feature of certain embodiments of this invention that a lossy dielectric material be inserted into the capacitance gaps thus defined in the anode structure.

It is a still further feature of this invention that a magnetron comprise hollow anode segments having capacitance gaps across the base thereof for the storage of energy of the unwanted modes of oscillation, the hollow portions serving as choke sections to prevent the shorting of the capacitance gaps by the anode segments themselves.

A complete understanding of this invention and of the various 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 plan view of the anode and cathode structures of the embodiment of Fig. 1 taken along the line 2—2 thereof; and

Fig. 3 is a partial plan view of an anode structure in accordance with another specific illustrative embodiment of this invention.

Referring now to the drawing, the specific illustrative embodiment of this invention depicted in Fig. 1 comprises an anode structure **10**, best seen in Fig. 2, mounted by a circular rim member **11** between the two pole pieces **12** and **13**. A cathode sleeve **15** extends through the central aperture of the anode **10** and has coated thereon an electron emissive coating between a pair of magnetic collars **17**. A heater element **19** extends within the cathode sleeve **15** and is connected to a pair of leads **20**. One lead **20** is connected to an inner cylindrical terminal conductor **21** and the other to an outer cylindrical terminal conductor **22**, the two terminals **21** and **22** being insulated from each other by a vitreous bead **23**. The cathode sleeve **15** is mounted by a supporting cylinder **25** secured to an end cap **26** which in turn is supported from the pole piece **13** by a vitreous cylindrical section **27** and a pair of metallic cylindrical sections **28** and **29**.

The output resonator **32** of the anode structure is conected, through a dumb-bell or basically H-shaped transformer section **33**, as is known in the art, to an output wave guide section **35** through which the energy of the magnetron is transmitted to external circuitry. The output wave guide section **35** serves as an impedance transformer between the output of the magnetron and the external circuitry and has hermetically sealed thereto a window **36** transparent to the passage of microwave energy.

Heat radiating vanes **38** are advantageously supported by a metallic body member **39** in which is also located the dum-bell shaped wave guide output section **33**. An exhaust tubulation **40** is secured to a side aperture in the pole piece **13** to enable the exhausting of the magnetron.

In this specific embodiment of the invention, the anode structure **10**, as seen in Fig. 2, comprises a plurality of hollow anode vanes or segments **45** which may advantageously be each formed of a single strip of a conducting material; each anode vane **45** encompasses a hollow choke section **46**. At the base of each vane **45** and extending inwardly across the hollow section **46** are a pair of capacitance gap defining members **47**; members **47** thus define a plurality of capacitance gaps **48** which serve to couple capacitively adjacent resonator slots **49** defined between adjacent anode vanes **45**.

The resonator slots **49** are open adjacent the central cavity of the anode, in which cavity the cathode sleeve **15** is located, and are each closed at their other end by a T-shaped support member **51**. Secured to each cross or T-section of members **51** are one side of each of two adjacent anode vanes **45** and the one capacitance member **47** connected to each side. Between adjacent cross or T-sections of members **51** there is thus defined a second capacitance gap **53**, which gap is directly adjacent and electrically parallel to the primary gaps **48** defined by members **47** secured to the base of the anode vanes **45**.

A hollow choke section **54** is defined between adjacent T-shaped members **51** by the adjacent members **51** and the supporting circular rim member **11**. The individual anode vanes **45** are thus each supported by two T-shaped members **51** which in turn are secured to the outer rim member **11**.

In accordance with an aspect of this invention, mode separation is attained by the capacitive coupling between adjacent resonators **49** afforded by the capacitive gaps **48** and **53** and specifically by the storage of field energy of unwanted modes in these gaps. Th hollow sections **46** and **54** define inductance chokes which prevent the capacitance gaps from being shorted by the conducting paths of the anode vane and support members, respectively. As the hollow section **46** within the anode vane **45** is limited in area, the capacitance gap **48** is advantageously of a sufficiently small size so that the choke section can adequately assure that the conducting path of the vane has a negligible shunting effect on the capacitance gap **48** associated with the vane. The hollow sections **54**, however, may be formed of substantially any desired size by increasing the diameter of the outer circular rim **11** and the length of the upright portions of the T-shaped members **51**. Capacitance gaps **53** accordingly may advantageously be larger than the primary capacitance gaps **48**.

The mode separation in the anode structure of Fig. 2 is attained by this capacitive coupling between adjacent resonators **49** and essentially across the base of each anode segment. The inductive chokes formed by the hollow sections **46** within the anode vanes **45** themselves prevent shorting of the capacitances thus formed between the two parts of the anode segments **45**. And the supporting members **51** for the anode vanes provide both additional coupling capacitance and another choke section to enable storage of more energy of the unwanted modes.

As there is no π-mode potential between adjacent resonators and thus there is only field energy of the unwanted modes stored in the coupling capacitances defined by gaps **48** and **53**, the unwanted modes may readily be loaded by inserting a lossy dielectric into these gaps. In the specific illustrative embodiment depicted in Fig. 3, this has been done. Advantageously the lossy dielectric **56**, which may be of barium titanate or other dielectric material having a high loss factor, is secured directly to the gap defining members; this may be done by plating a thin layer of silver onto the sides of the dielectric material **56** and silver brazing the silver plated dielectric material to the sides of the gap defining members.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A magnetron comprising a plurality of anode segments defining resonant cavities between adjacent seg-

ments, said segments having hollow portions therein, and capacitance members at the base of said segments across said hollow portions and defining capacitance gaps for the storage of energy of unwanted modes of oscillation, said hollow portions serving as choke sections to prevent the shorting of said capacitance gaps by the anode segments.

2. An anode for employment in magnetrons comprising a plurality of anode segments defining resonant cavities between adjacent segments, said segments having hollow portions therein, capacitance members at the base of said segments across said hollow portions and defining capacitance gaps, and means supporting said anode segments.

3. An anode in accordance with claim 2 wherein said supporting means comprises conductive means defining second capacitance gaps positioned adjacent said first-mentioned gaps, said conductive means having hollow portions communicating with said second capacitance gaps.

4. An anode in accordance with claim 3 wherein said second capacitance gaps are longer than said first-mentioned capacitance gaps.

5. An anode for employment in magnetrons comprising a plurality of anode segments defining resonant cavities between adjacent segments, said segments having hollow portions therein, capacitance members at the base of said members extending inwardly across said hollow portions and defining capacitance gaps, means supporting said anode segments, and lossy dielectric elements positioned in said gaps.

6. A magnetron comprising a cathode, a plurality of anode segments encompassing said cathode, said anode segments defining resonant cavities between adjacent segments and said segments having hollow portions therein, capacitance members at the base of said segments and extending inwardly across said hollow portions, the capacitance members of each segment defining a capacitance gap for storage of energy of unwanted modes of oscillation of the magnetron and the impedances of said gaps and said hollow portions being such that said gaps are not appreciably shunted by said anode segments, and means supporting said anode segments.

7. A magnetron in accordance with claim 6 comprising lossy dielectric elements positioned in said gaps to load the unwanted modes of oscillation of the magnetron.

8. A magnetron in accordance with claim 6 wherein said supporting means comprises conductive means defining second capacitance gaps positioned adjacent said first-mentioned gaps, said conductive means having hollow portions communicating with said second gaps and the impedances of said second gaps and said second-mentioned hollow portions being such that said second gaps are not appreciably shunted by said conductive means.

9. A magnetron in accordance with claim 8 comprising lossy dielectric elements positioned in said gaps to load the unwanted modes of oscillation of the magnetron.

10. A magnetron comprising a cathode, a plurality of anode segments encompassing said cathode and defining resonant cavities between adjacent anode segments, means including portions of said segments defining a capacitance gap between each two adjacent resonant cavities, and means supporting said anode segments, said supporting means including conductive means defining a second gap between adjacent resonant cavities.

11. A magnetron comprising a cathode, a plurality of anode segments encompassing said cathode and defining resonant cavities between adjacent anode segments, means including portions of said segments defining a capacitance gap between each two adjacent resonant cavities, means supporting said anode segments, and lossy dielectric elements positioned in said gaps.

12. A conductive circuit element comprising a plurality of hollow conductive members, means mounting said conductive members circumferentially, adjacent ones of said conductive members defining resonant cavities, and a pair of conductive elements mounted on each of said hollow conductive members external of said resonant cavities and extending inwardly across the hollow thereof, said conductive members defining capacitance gaps between adjacent ones of said resonant cavities.

13. A conductive circuit element in accordance with claim 12 comprising lossy dielectric elements positioned in said gaps.

14. A conductive circuit element in accordance with claim 12 wherein said mounting means comprises means defining second capacitance gaps and having apertures therein communicating with said second gaps.

15. A conductive circuit element in accordance with claim 14 comprising lossy dielectric elements positioned in said priorly mentioned and said second gaps.

16. A conductive circuit element in accordance with claim 14 wherein said second gaps are larger than said priorly mentioned gaps and said apertures are larger than the hollow defined by said conductive members.

17. A conductive circuit element comprising a plurality of thin vane segments, means mounting said segments circumferentially, adjacent ones of said segments defining resonant cavities therebetween, and a pair of conductive members mounted on each of said vanes at the base thereof and extending inwardly of each segment, each pair of conductive members defining a capacitance gap across the base of each segment.

18. A conductive circuit element in accordance with claim 17 wherein said mounting means comprises means defining a second capacitance gap adjacent each of said priorly mentioned gaps and communicating therewith and having an aperture therein adjacent each of said second gaps and communicating therewith.

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