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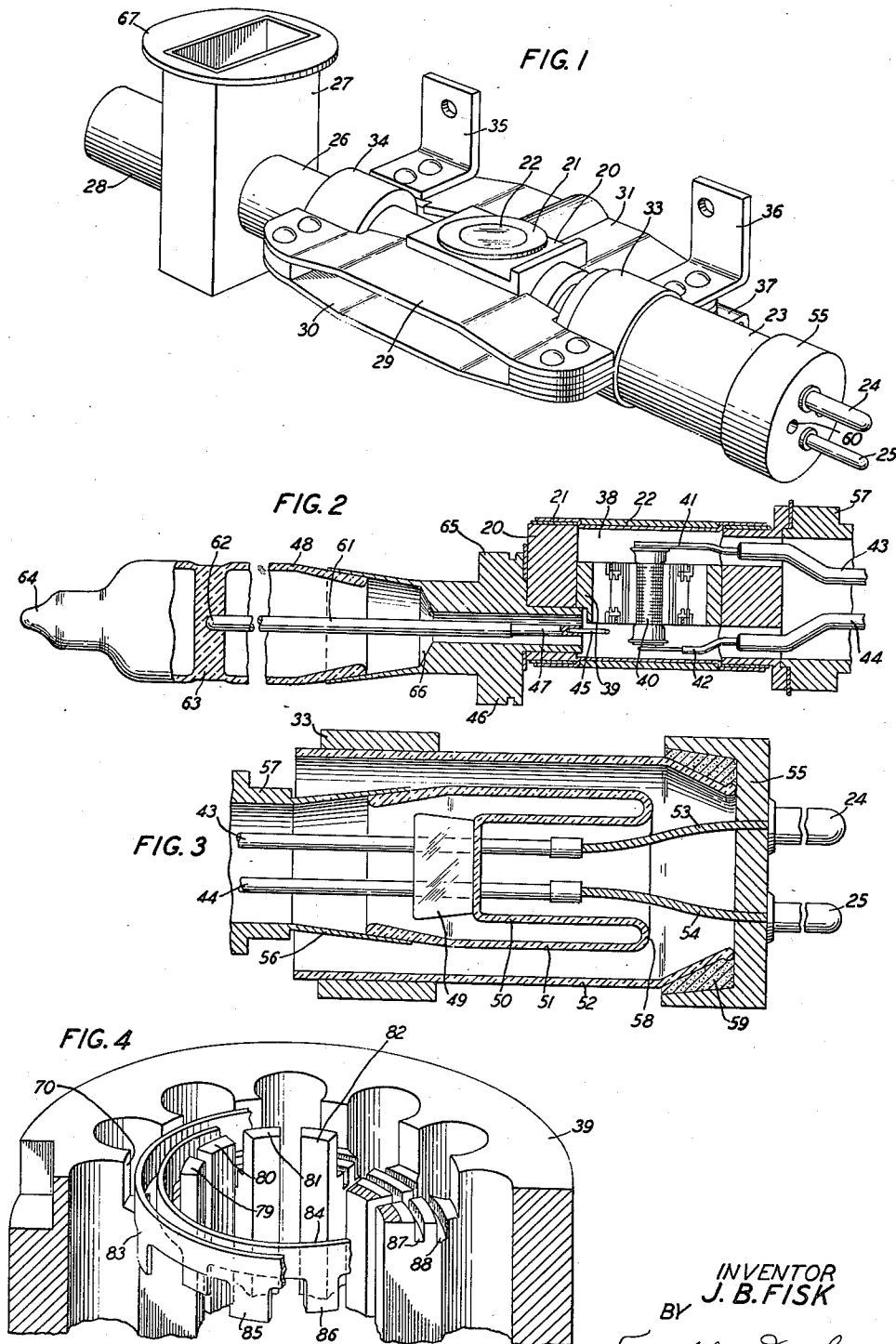
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2,595,652

COUPLED CAVITY RESONATOR

Filed April 5, 1944

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

FIG. 8

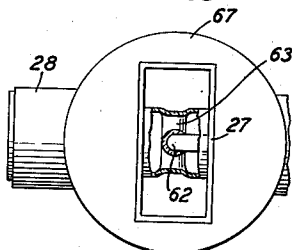


FIG. 9

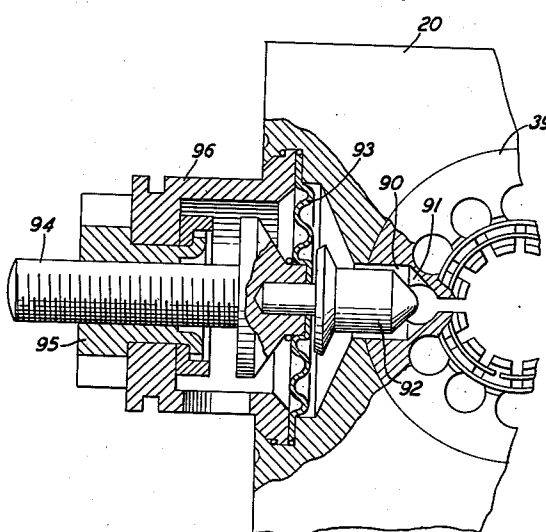


FIG. 5

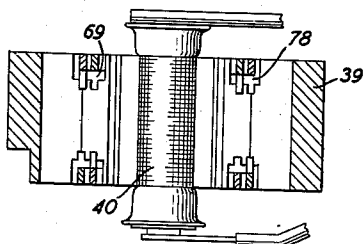


FIG. 10

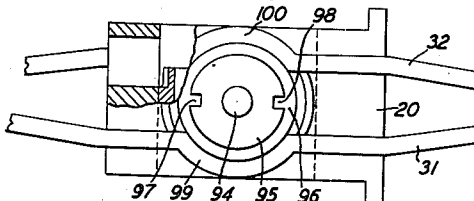


FIG. 6

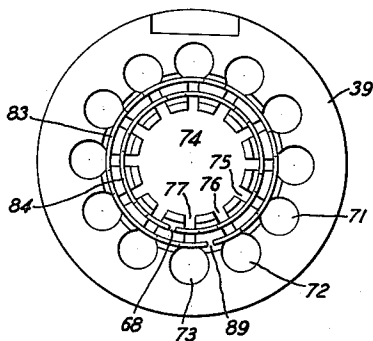
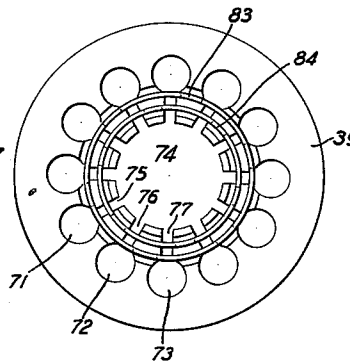


FIG. 7



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COUPLED CAVITY RESONATOR

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7 Claims. (Cl. 315-40)

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This invention relates to coupled systems of cavity resonators, particularly for use in multi-anode magnetrons, in which interanode straps are employed to influence the separation of the resonant frequencies and in which the straps are shielded to reduce their reaction with the electromagnetic field in the space between the cathode and the anode segments.

A resonating system such as commonly is employed in multianode magnetrons comprises a plurality of coupled cavities, the resonating system as a whole, on account of the coupling, having a plurality of resonant frequencies. The distribution and separation of the resonant frequencies are dependent upon the nature and degree of the coupling between the cavities, often in a very complicated manner. In the operation of a given resonant structure in an oscillator, the oscillations are generally found to be restricted to one of the several resonant frequencies, the particular one depending upon various parameters of the excitation system. Sometimes during operation the operating frequency may change in an erratic and unpredictable manner from one resonant frequency to another. For each resonant frequency the distribution of currents and electric and magnetic fields has a characteristic pattern in space and the operation of the system with a particular space pattern is termed a mode of oscillation. Usually the modes of oscillation are distinguished from each other by different frequencies, although in special cases two modes may have the same frequency but a different pattern of currents and fields.

In practice it is usually desirable to design a magnetron for a particular mode of oscillation and to discourage or prevent oscillation at other modes. It has been found that the particular mode of oscillation which will be set up in a given system may be influenced by the use of conductive or inductive straps connecting predetermined selected points of the anode structure. The straps, among other possible effects, introduce more or less concentrated capacitances between surfaces of straps which are opposed and between surfaces of the straps and adjacent portions of the anode. These capacitances have been found also to influence the separation of the resonant frequencies and in general the tendency of the magnetron to confine its oscillations to a particular mode increases with the degree of frequency separation.

Among magnetrons which are equipped with straps that are effective to provide a good frequency separation between modes, it has been

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noted that there are considerable differences in their efficiency of power conversion, depending upon the form and arrangement of the strapping. A high efficiency has been found to depend upon having a uniform angular distribution of the field pattern with respect to the central axis of the magnetron. The efficiency has also been found to depend upon having a uniform field pattern from one end of the reaction space to the other, that is, over the full length of the cathode and anode. In the case of an inefficient magnetron the electronic reaction with the resonant circuits may be different near the ends of the anode-cathode space from what it is near the middle. A magnetron to be highly efficient should have an equally effective reaction at all points along the length of its reaction space.

It is to this latter requirement that the present invention is particularly directed, consistently with a good frequency separation of modes and a uniform angular distribution of the field pattern.

In accordance with the invention, the straps are depressed in a groove in the anode structure, the groove surrounding the anode-cathode space and the material of the anode structure situated between the groove and the anode-cathode space serving to shield the space from the electromagnetic influence of the straps.

While the invention is applicable to multicavity resonators in general, the embodiment illustrated herein comprises a multianode magnetron.

In the drawings,

Fig. 1 is a perspective view showing the general external appearance of the particular magnetron structure selected to illustrate the invention;

Figs. 2 and 3 together represent a longitudinal section of the magnetron of Fig. 1 partially dismantled to show the principal operating parts, the view being broken into two sections to permit the use of an enlarged scale;

Fig. 4 is an enlarged perspective view of a fragment of the anode structure showing the straps and shielding elements partly broken away;

Fig. 5 is an enlarged sectional view of the anode structure with the straps in place;

Figs. 6 and 7 are plan views of opposite ends of the anode structure showing the relative positions of the straps, grooves and shielding elements as well as the anode-cathode space and the coupled resonating cavities;

Fig. 8 is a detail of an output circuit feeding a wave guide that may be made integral with the magnetron structure;

Fig. 9 is a sectional view of a mechanical tuning arrangement which may be integral with the magnetron structure; and

Fig. 10 is an elevational view partly in section showing the external appearance of the tuning device.

Referring particularly to Fig. 1, the casing of the magnetron structure proper is shown at 20 in the form of a rectangular block having a circular end plate 21 containing a circular magnetic insert 22. A sheath 23 encloses arrangements for heater and cathode leads which terminate in prongs 24 and 25. At the opposite end of the magnetron casing 20 is a coaxial output fitting having an outer sheath 26 joined to an output wave guide fitting 27. A pumping out seal is contained within a protective sheath 28 also attached to the fitting 27. Radiating fins 29, 30, 31 and 32 are arranged in thermal contact with the casing 20 and may be fastened to clamping members 33 and 34 which serve to retain respectively the sheaths 23 and 26. The fin 32 which is hidden in Fig. 1 is shown in fragmentary view in Fig. 10. Mounting lugs such as 35, 36 and 37 may be attached to the assembly as shown in Fig. 7.

In Fig. 2, the magnetron casing 20, cover plate 21 and magnetic insert 22 are shown in section. The casing 20 has a cylindrical hole 38 into which is fitted an anode insert 39 in the form of a perforated metal block, through which extends a cathode 40. Cathode heater leads 41 and 42 come out radially from the ends of the cathode through suitable holes in the casing 20 and may be connected respectively to rigid conducting supports 43 and 44, respectively. An output coupling loop 45, shown edge-on and broken open in Fig. 2, is arranged in one of the end spaces adjacent to one of the perforations of the anode block 39. The loop 45 may be connected at one end in known manner to a conductive bushing 46 and at the other end to a conductor 47 concentric with the bushing 46, members 46 and 47 constituting together a coaxial output lead for the loop 45.

In Fig. 3, the cathode heater leads 43 and 44 pass through a press 49 which is attached to the inner one of three concentrically arranged tubulations 50, 51 and 52. Outside the press 49 and within the tube 50 the leads 43 and 44 may be attached to flexible leads 53 and 54, respectively, which may pass through holes in a cup-like base member 55 and connect respectively to the prongs 24 and 25.

The tubulation 51 surrounds the press 49 and tube 50 and is sealed into a tapered and flaring edge 56 formed on a conductive bushing 57 which is attached to the casing 20 in a position surrounding the leads 43 and 44 and sealing up the holes through which the leads leave the casing 20. The tubulations 50 and 51 are joined together by an annular bead 58. The outermost tubulation 52 is cemented into the base 55 by a suitable basing compound as at 59 and serves as a protection for the cathode lead seal and as a bearing surface for the clamp 33. Ventilation around the heater lead seal through the open end of the tubulation 52 may be provided by means of a hole 60 (Fig. 1) through the base 55.

The tubulation 48 may be sealed to a tapered and flaring portion of the bushing 46 as shown in Fig. 2. The inner conductor 47 may be joined to a more rigid conductor 61 which serves also as an antenna for launching an output wave into the wave guide output fitting 27. The end 62 of the rod 61 is preferably supported in a

vitreous column 63 (Figs. 2 and 8) which does not entirely fill the interior of the tubulation 48 but leaves room on either side for an air passage which can be used in exhausting the magnetron through the tubulation 48. After pumping, the tube may be sealed off by forming a tip 64 in the usual manner.

The sheath 26 may be fitted over a flange 55 of the bushing 46 and may open into the wave guide fitting 27 at the opposite end through a circular hole in the wall of the wave guide. An impedance transformation may be afforded in efficient manner by a suitable tapering of the wall of the bushing 46 as at 66 (Fig. 2). The tubulation 48 may continue through the wave guide and be protected by the cylindrical casing 28 as shown in Figs. 1 and 8. The end 62 of the conductor 61 is preferably extended a predetermined distance into the wave guide 27 as shown in Fig. 8. A flange 67 may be provided on the wave guide 27 for coupling mechanically and electrically to any desired output system.

The anode block 39 is shown in fragmentary view in Fig. 4 and in sectional view in Fig. 5. Plan views from opposite ends of the anode block are shown in Figs. 6 and 7. The block 39 may be cylindrical in form and may contain a plurality of circular cylindrical cavities such as 71, 72 and 73 connected with a central cylindrical space 74 by means of substantially radial slots as at 75, 76 and 77. At either end, concentric with the central space 74, a circular groove 78 (Fig. 5) may be formed intersecting the cavities 71, 72 and 73 and the slots 75, 76 and 77, leaving upright shielding members as at 79, 80, 81 and 82 at the edge of the opening 74 as shown more clearly in some respects in Fig. 4.

In the groove 78 may be mounted a plurality of straps such as 83 and 84 which may be in the form of ribbons or bands of conductive material. These straps 83 and 84 may be fastened to a plurality of the anode segments. Electrical and mechanical connection of the straps to the segments may be made in any suitable manner as by soldering or brazing and, if desired, the straps may be formed with integral feet as at 85 and 86 which may be suitably engaged in smaller grooves 87 and 88 formed in the bottom of the main groove 78.

Any desired system of connections may be employed as, for example, as shown in Figs. 6 and 7 where the outer strap 83 is connected to alternate anode segments and the inner strap 84 is connected to the remaining anode segments. The straps may be endless rings or they may be broken as at 89 and 90 in Fig. 6 to facilitate assembly or to conform to any desired scheme of strapping. The straps are shown as endless in Fig. 7. The straps 83 and 84 are shielded from the anode-cathode space comprised in the opening 74 by means of the shielding members such as 79 to 82, inclusive.

The points where the strap is connected to an anode segment are at relatively low potential with respect to the intermediate points where the strap passes over an anode segment with a clearance as shown at 69 in Fig. 5. In the case of the outer strap 83 in the strapping scheme shown in Fig. 6 or Fig. 7, a high potential portion of the outer surface of the strap is opposite a portion of the outer wall of the groove 78, such as the segment 70 in Fig. 4. A high potential portion of the inner surface of the strap 83 is opposite a low potential portion of the inner strap 84, since the inner strap is connected to

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the bottom of the groove 78 opposite the surface 70. On the other hand, a high potential portion of the outer surface of the inner strap 84 is opposite a part of the strap 83 which is fastened to an anode segment, hence at low potential and a high potential portion of the inner surface of the inner strap 84 is opposite one of the shielding members 79 to 82, inclusive. The arrangement thus furnishes a systematic shielding scheme whereby the anode-cathode space is substantially completely shielded from electromagnetic influence of the straps.

A mechanically adjustable tuning device for the magnetron is illustrated in Figs. 9 and 10. A cylindrical aperture 90 terminating in a conical recess 91 is formed to open into one of the cylindrical resonating cavities in a radial direction, preferably midway between the ends of the cavity and entering the anode block 39 through a portion of the casing 20. In this aperture and recess there is arranged a plunger 92 suitably attached to a flexible diaphragm 93 and to a threaded bolt 94. A captive nut 95 is retained on the threaded portion of the bolt 94 by a suitable retaining member 96. Recesses are cut as required into the casing 20 to accommodate the diaphragm 93 and retaining member 96 as shown in Fig. 9. Fig. 10 shows an end elevation of the bolt 94, the nut 95 and the retainer 96. The nut 95 may be provided with suitable slots 97 and 98 for reception of a screw-driver or similar tool for adjusting the position of the plunger 92. Access to the tuning device is conveniently furnished within cylindrical segments 99 and 100 respectively formed in the radiating fins 31 and 32. The diaphragm 93 is preferably attached by vacuum-tight seals to the plunger 92 and the casing 20.

In an embodiment of the invention which has been built and successfully operated at a frequency in the neighborhood of 10,000 megacycles (3 centimeter wavelength) the anode insert 39 had an outer diameter of .595 inch and a length of $\frac{1}{4}$ inch. Twelve resonating cavities each having a diameter of .079 inch were symmetrically disposed with their centers lying on a circle of diameter .391 inch concentric with the anode block. The central reaction space 74 has a diameter of .204 inch and contains a central cathode of diameter .105 inch. The main groove 78 containing the straps has an outside diameter of .346 inch and an inside diameter of .234 inch and was cut to a depth of .047 inch with a flat bottom. The outer strap 83 was a cylindrical band with an inside diameter of .302 inch, a thickness of .0098 inch and a breadth of .035 inch. The total height of the strap including the legs was .067 inch. The inner strap 84 was similar to the outer strap except that the inside diameter was .258 inch. The legs of the straps were set into the small grooves 87 and 88, respectively, the bottoms of the small grooves extending .067 inch from the end surface of the anode insert thus bringing the tops of the straps flush with the end surface. The anode insert is mounted equidistant from end plates separated by approximately $\frac{1}{2}$ inch.

What is claimed is:

1. An electron discharge device having a plurality of anode segments extending radially from a central space defined by said segments, a cathode adjacent said anode segments for supplying electrons within said central space, said segments comprising slat-like elements, said slat-like elements having slots in one end thereof, and concentric ring-shaped strapping elements having

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extensions normal to the plane of the element, the extensions of one of said ring-shaped strapping elements contacting alternate slat-like elements within the slots, and the extensions on another ring-shaped strapping element lying within the slots of and connecting the remaining slat-like elements together.

2. An electron discharge device having a plurality of anode segments extended radially from a central space defined by said segments, a cathode adjacent said anode segments for supplying electrons within said central space, said segments having slots in one end thereof, and concentric ring-shaped strapping elements having extensions, the extensions of one of said ring-shaped strapping elements contacting alternate anode segments within the slots, and the extensions on another of said ring-shaped strapping elements lying within the slots and connecting the remaining anode segments together at the same end of the anode.

3. An electron discharge device having a plurality of anode segments extending radially from a central space defined by said segments, a cathode adjacent said anode segments for supplying electrons within said central space, said segments having slots in one end thereof, and concentric ring-shaped strapping elements one of which contacts alternate anode segments within the slots, and another of which ring-shaped strapping elements connects the remaining anode segments together at the same end of the anode.

4. An electron discharge device having a plurality of anode segments defining between each pair of adjacent anode segments a cavity resonator, and said anode segments defining a reaction space communicating with said cavity resonators; a cathode adjacent said anode segments for supplying electrons within said reaction space, said segments having slots in one end thereof, and concentric ring-shaped strapping elements positioned within a plurality of said slots, one of said strapping elements contacting alternate anode segments within the slots, and another of said strapping elements contacting the remaining anode segments within the slots at the same end of the anode.

5. An electron discharge device having a plurality of anode segments extending radially from a central space defined by said segments, a cathode adjacent said anode segments for supplying electrons within said central space, said segments each having a slot at each end thereof, and concentric ring-shaped strapping elements, one of said strapping elements contacting alternate anode segments at one end of the anode, a second of said strapping elements contacting the remaining anode segments at the same end of the anode, a third strapping element contacting alternate anode segments at the other end of the anode, and a fourth strapping element contacting the remaining anode segments at that end of the anode.

6. Apparatus comprising a block of conductive material constituting a plurality of cavity resonators, with intermediate segments of the conductive material therebetween, said block having a reaction space therein communicating with the interior of said cavity resonators, and said block having a face intersecting said resonators and said reaction space and having a groove in said face surrounding said reaction space, and a pair of concentric ring-shaped conductive straps mounted within the limits of said groove, one said strap being connected to alternate intermediate

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segments and the other strap being connected to the remaining intermediate segments to influence the resonant frequencies of the combination, the material of said block situated between said groove and said reaction space constituting a shield for shielding said reaction space from the electromagnetic influence of said straps.

7. A space discharge device comprising a cathode and an anode having respective opposing surface portions defining a reaction space therebetween in which electrons from said cathode may react with an electromagnetic field in the vicinity of said anode, the anode comprising a block of conductive material having a plurality of segments and having a groove in a portion of its surface adjacent to the portion opposing the cathode surface and intersecting said segments, said block having a solid portion between said groove and said reaction space, and a plurality of concentric ring-shaped straps depressed within

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said groove, one of said straps connecting alternate anode segments and another of said straps connecting the remaining anode segments.

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