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VOLTAGE-TUNABLE MAGNETRON

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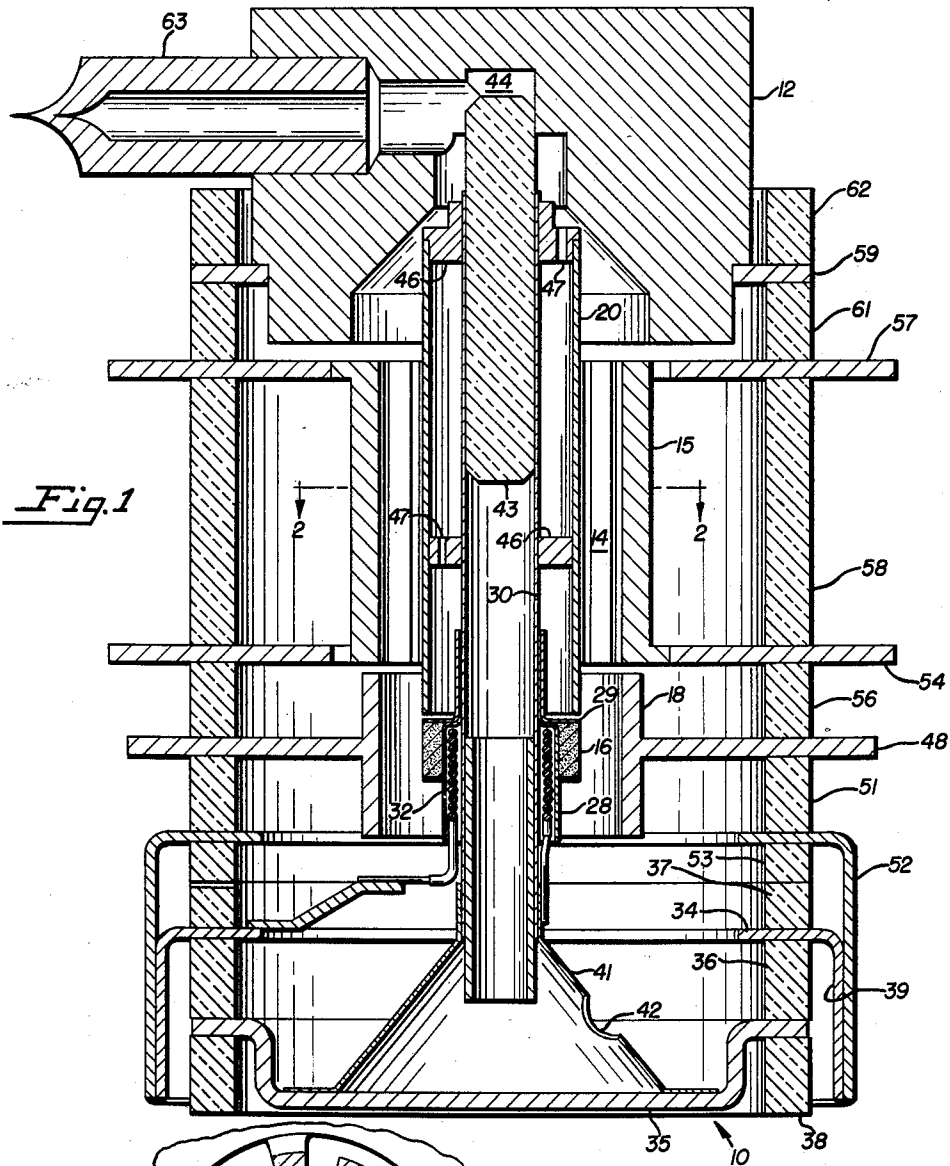


Fig. 1

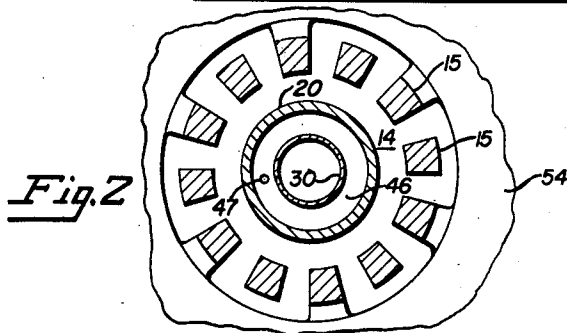


Fig. 2

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VOLTAGE-TUNABLE MAGNETRON

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This invention relates to magnetrons and, particularly, to an improved voltage-tunable type magnetron vacuum tube.

A magnetron produces high frequency electromagnetic oscillations because electrons are caused to spiral by an axially parallel magnetic field within a cylindrical interaction space. The interaction space is formed by an annular anode block, and the electrons are emitted by a cylindrical cathode disposed coaxially within the interaction space. The anode block has an even number of resonators formed by elongated cavities disposed around the anode and aligned parallel to the tube axis. The cavities communicate with the interaction space by slots which extend the full length of the anode. As the electrons spiral around and outward from the cathode, the resonators are excited so that electromagnetic oscillations are formed therein, which in turn velocity modulate the spiraling electrons. The electrons form spiraling bunches which further excite the resonators to a high-energy level. The electrons give up their energy to the high frequency electromagnetic energy in the resonators as they spiral outwardly from the cathode and are then collected on the anode. The magnetron as described is a fixed tuned (fixed frequency) device.

Magnetrons which can be tuned by varying the potential between the anode and the cathode, as shown in U.S. Patents 2,810,095 and 2,810,096, are known as voltage-tunable magnetrons. These patents teach that the emissive cathode should be a filamentary type with the emissive area axially displaced so that it is adjacent one end but exterior to the interaction space. The anode is made of elongated, thin segments disposed parallel to each other and in a circular array around a cold cylindrical non-emissive "cathode," thus producing a low Q resonator. A control electrode having a frusto-conical interior surface guides the electrons into the interaction space between the cold cathode and the anode segments. But, since in a voltage-tunable magnetron the magnetic field cannot be removed from within the region formed by the control electrode, and the hot emissive cathode will be subjected to some back heating by some of the electrons gaining energy from the high frequency electromagnetic energy and returning to the hot emissive cathode, if the hot cathode is a filament having little mass, small lengths of the filament become hotter, thereby increasing the number of emitted electrons. This condition is incompatible with voltage tuning. Although this back heating effect of the emissive cathode is not as large as it would be if the cathode were located within the interaction space, it is nevertheless present.

An object of this invention is to prevent excessive heating of a hot cathode by the returning spiraling electrons.

Another object of this invention is to provide a massive hot cathode which shows little or no effect from heating by the returning electrons.

The prior art teaches the use of a reflector electrode to reflect the electrons back into the interaction space. The electrons must then be collected on the long thin segments, thereby overheating them. The reflected electrons are slightly out of phase with the high frequency, thereby producing noise.

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Another object of this invention is to reduce the number of electrons collected by the segments and thereby prevent segment overheating.

Yet another object of this invention is to reduce the noise level of a voltage-tunable magnetron.

A further object of this invention is to provide a collector at the end of the interaction space remote from the hot cathode.

In terms of broad inclusions the novel magnetron has a hot cathode disposed on the axis of an interaction space. The hot cathode is axially shifted so that it is outside the interaction space so that a deflector or control electrode positioned around the hot cathode is required to deflect the electrons within the interaction space. At the other end of the interdigital line is disposed a collector which collects the electrons after they helically pass through the interaction space. The hot cathode is preferably a massive matrix-type whereby any returning electrons have little effect on the temperature of the cathode.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of the invention. The invention is not limited to the disclosed embodiment, as variant embodiments thereof are contemplated and may be adopted within the scope of the claims.

Referring to the drawing:

FIGURE 1 shows in cross-section the voltage-tunable magnetron; and

FIGURE 2 is a view of the magnetron taken on line 2—2.

Referring to the drawing in greater detail, there is shown a magnetron tube with a cathode support 10 at one end, collector 12 at the other end, and between the two a cylindrical interaction space 14 formed by at least two sets of elongated, thin segments 15 disposed in a circular array. A hot electron-emitting cathode 16 emits electrons which are guided into the interaction space 14 by a control electrode 18. A magnetic field axially aligned with the interaction space 14 causes the electrons to spiral around a cold non-emitting electrode 20, which is at the same potential as the hot cathode 16. The electrons travel in an essentially helical path axially along the tube until they are collected on the collector 12 at the other end of the tube. The electrons travel this spirally helical path because the control electrode 18 is at a positive potential relative to the hot cathode, thereby attracting the electrons radially outward into the annular transition space the outer periphery of which is defined by the tubular control electrode and the inner periphery of which is defined in part by the cathode and adjacent end of the non-emitting electrode 20. Since the electrons are affected by a force which is perpendicular to the axially aligned magnetic field, the electrons are caused to spiral around the axis of the tube. Also, the electrons are attracted from the transition space into the interaction space aligned therewith by a potential on the segments 15, which potential is more positive than the potential of control electrode 18.

Since the electrons emitted by the hot cathode 16 are caused to spiral by the magnetic field, some of the electrons will return to the hot cathode 16 and give up their energy to the hot cathode. Since these returning electrons are few in number, and since the hot cathode 16 is a solid mass of emitting material which comprises a porous sintered-nickel base having oxides of either barium, strontium or calcium interposed within the pores, the small amount of energy from the returning electrons is transferred evenly within the solid mass of the cathode 16 and the temperature of the mass is slightly affected and the emissive rate is not noticeably affected. A cathode formed of porous sintered-nickel with barium, stron-

tium, or calcium oxides interposed within the pores is known as a matrix-type cathode. The matrix cathode 16 is mounted between a tubular metallic sleeve 28 and a non-emitting metallic radial flange 29, which are in turn mounted on an axial metallic sleeve 30 extending almost the length of the magnetron. Between the axial sleeve 30 and the tubular sleeve 28 is disposed a heating filament 32.

The heating filament 32 is preferably a double helically wound type which has one lead connected to a first terminal ring 34 and the other lead connected to the end metallic vacuum wall 35 of the magnetron tube. A first ceramic insulator 36 separates the end wall 35 from the first terminal ring 34, and a first ceramic backing ring 37 backs up the metal-ceramic seal at the terminal ring 34, and a second ceramic backing ring 38 backs up the metal-ceramic seal at the end wall 35. The first terminal ring 34 is also a sealing ring which has a flange 39 turned parallel to the axis of the tube. The axial sleeve 30, on which the hot cathode 16 is mounted, is preferably made of a thin-wall tube which acts as a heat dam holding the heat of the filament 32 in the region of the cathode 16. The thin-wall axial sleeve 30 is mounted at one end on a thin-wall conical support 41 which has an aperture 42 for easy evacuation. The conical support 41 is mounted on the metallic end wall 38. The other end of the axial sleeve 30 fits over a ceramic rod or post 43 which fits into a well 44 formed in the collector 12. The cold electrode 20 is supported on the axial sleeve 30 by two metal rings 46 having apertures 47 for easy evacuation. As shown in FIGURE 1, the non-emitting electrode 20 is spaced and therefore electrically insulated from the collector, the only connection between these two members being a mechanical connection provided for support of the non-emitting electrode by ceramic post 43, which is conveniently formed from the same type ceramic as electrical insulator ceramic 36. The ceramic post thus does not electrically connect the non-emitting electrode with the collector. Thus, the cathode support 10, which is one sub-assembly of the magnetron, is formed.

The other assembly of the magnetron comprises the control electrode 18 which is preferably made cylindrical with an inner diameter equal to the outer diameter of the interaction space 14 formed by the segments 15. The control electrode 18 is mounted on a second terminal ring 48. A second ceramic insulator 51 separates the second terminal ring 48 from a sealing ring 52, and a third ceramic backing member 53 is disposed on the opposite side of the sealing ring 52. The segments 15 are attached to the body of this sub-assembly in the manner taught in the prior art. Alternate or every other one of the segments 15 constitute a set and are mounted on a third terminal ring 54 which is insulated by a third ceramic insulator 56 from the second terminal ring 48, and the remaining segments 15 constitute a second set and are mounted on a fourth terminal ring 57 which is insulated by a fourth ceramic insulator 58 from the third terminal ring 54. Then the collector 12 is fixed to this sub-assembly by a fifth terminal ring 59 bonded to a fifth ceramic insulator 61, which is in turn bonded to the terminal ring 57. A ceramic backing member 62 is bonded to terminal ring 59 opposite the ceramic insulator 61. An exhaust tubulation 63 is disposed in the collector 12.

Thus, the magnetron is shown preferably made in two sections which are welded together at the edges of flange 39 and the sealing ring 52. The cold electrode 20 on the cathode support 10 fits within the interaction space 14 and the ceramic rod 43 fits snugly into well 44 of the collector, whereby the cathode elements are aligned within the interaction space. The welded envelope is evacuated by the tubulation 63.

The magnetron operates in the following manner: An external magnetic circuit (not shown) forms a relatively uniform magnetic field within the interaction space 14

oriented parallel to the tube axis. The hot cathode 16 emits electrons which are attracted by the control electrode 18. The electrons, being thus subjected to a force which is oriented radially outward and perpendicular to the magnetic field, are caused to spiral around the axis of the magnetron. The segments 15 around the interaction space 14, being more positive than the control electrode, attract the spiraling electrons within the interaction space 14. When the electrons reach the interaction space, they are velocity modulated to form bunches, and bunches in turn form electromagnetic oscillations in the segments. The electrons are now traveling in a path which is helically along the axis. When the electrons reach the other end of the interaction space, they are collected on the collector 12 and prevented from re-entering the interaction space 14. This reduces the noise in the high-frequency circuit because out-of-phase electrons are removed from the interaction space. Electrical energy is extracted from the magnetron by means of terminals 54 and 57. Normally, the leads at one end of a two-conductor strip transmission line are connected to terminals 54 and 57, and the other end of the line is connected to a coaxial transmission line or a waveguide.

We claim:

1. A magnetron comprising an anode having a cylindrical interaction space therethrough, an elongated non-emitting electrode coaxially disposed within said interaction space, an electron emitting cathode spaced axially from said interaction space, a control electrode surrounding said electron emitting cathode, and a collector electrode spaced from said non-emitting electrode in non-conducting electrical relation therewith and disposed on the side of said anode remote from said electron emitting cathode.

2. The magnetron of claim 1, wherein said anode comprises an even number of resonant cavities communicating with said interaction space.

3. The magnetron of claim 1, wherein said anode comprises a plurality of elongated, parallel spaced segments supported in a cylindrical array forming said interaction space therein, every other one of said segments being electrically connected together, and the remaining ones of said segments being electrically connected together.

4. A magnetron comprising an anode having a cylindrical interaction space therethrough, an elongated non-emitting electrode coaxially disposed within said interaction space, and an electron emitting cathode spaced axially from said non-emitting electrode, said electron emitting cathode comprising a ring of porous metal and having a metal oxide chosen from the group of barium oxide, strontium oxide, and calcium oxide interposed within its pores.

5. The magnetron of claim 4, wherein said electron emitting cathode and said non-emitting electrode, being tubular, are mounted coaxially on an axially disposed thin-wall metallic sleeve, and a filament is disposed between said thin-wall sleeve and said cathode for heating said cathode.

6. The magnetron of claim 5, wherein said electron emitting cathode comprises a short tubular metallic sleeve fixed to the inner periphery of said ring of porous metal and a metallic radial flange fixed to one end of said ring of porous metal, whereby electrons are emitted only from the exposed periphery and the other end of said ring of porous metal.

7. A magnetron comprising an anode having a cylindrical interaction space formed by a plurality of elongated parallel spaced segments supported in a cylindrical array, every other one of said segments being electrically connected together, and the remaining ones of said segments being electrically connected together, an axially disposed thin-wall metallic sleeve, a tubular non-emitting electrode coaxially disposed within said interaction space, an electron emitting cathode formed from a ring of porous metal and having a metal oxide chosen from the group of

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barium oxide, strontium oxide, and calcium oxide interposed within its pores, said cathode being mounted coaxially on said thin-wall sleeve and spaced from said non-emitting electrode and from one end of said interaction space, a filament for heating said cathode disposed between said thin-wall sleeve and said cathode, a tubular control electrode disposed coaxially around said cathode, a collector disposed and spaced from the other end of said interaction space, and an insulating rod disposed between said collector and said thin-wall axial sleeve for supporting said sleeve.

8. A magnetron comprising an envelope wall portion to which is attached a collector, an anode, and a control electrode, a sealing ring attached to said envelope portion, a second envelope wall portion to which is attached a cathode, and a non-emitting electrode, a second sealing ring attached to said second envelope portion and a vacuum tight bond joining said sealing rings, said collector being positioned adjacent one end of said magnetron and having a well therein opening toward the other end of said magnetron, said anode having a bore therethrough and being positioned adjacent said collector, said control electrode being positioned adjacent the end of the anode remote from the collector and having a bore therein axially aligned with the anode bore, a tubular structure extending coaxially through said bores, said non-emitting electrode comprising a cylinder passing through said bore in the anode, said cathode being attached to said tubular structure at a position between said anode and the end of the magnetron remote from said collector, a post attached to one end of said tubular structure and at its other end engaging the collector, and mechanical means connecting the other end of said tubular structure to said second envelope wall portion.

9. A magnetron comprising a first tubular envelope wall portion to which is attached a collector, an anode, and a control electrode, said collector closing one end of said first tubular envelope wall portion, a first sealing ring attached to the other end of said first envelope wall portion, said anode being disposed between said collector and said first sealing ring and comprising a plurality of elongated, parallel spaced segments supported in a cylindrical array to form an interaction space therein, every other one of said segments being electrically connected together to a first ring electrode extending through said first envelope wall portion and the remaining ones of said segments being electrically connected together to a second ring electrode extending through said first envelope wall portion, said control electrode being positioned adjacent the end of the anode remote from the collector and having a bore therein axially aligned with said interaction space, a second tubular envelope wall portion to which is attached a tubular cathode, an axially aligned non-emitting tubular electrode within said first tubular envelope wall portion, an end plate closing one end of said second envelope wall portion, a tubular structure fixed coaxially on said end plate, said cathode being mounted on said tubular structure, a second sealing ring disposed on the other end of said second envelope wall portion, a post interposed between the free end of said tubular structure and the collector, said first and second envelope wall portions being disposed in axially aligned relationship with said first and second sealing rings bonded together, said cathode being spaced axially from said interaction space, and said non-emitting electrode disposed within said interaction space.

10. A magnetron comprising a tubular envelope, a collector, an anode, a control electrode, a cathode, and a non-emitting electrode, said collector being positioned adjacent one end of said envelope and having an axially aligned well therein opening toward the other end of said magnetron, said anode having an axially aligned bore therethrough and being positioned adjacent said collector, said control electrode being positioned adjacent

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the end of the anode remote from the collector and having a bore therein axially aligned with the anode bore, a tubular structure extending coaxially through said bores, said non-emitting electrode being a cylinder surrounding said tubular structure and passing through said bore in the anode, said cathode being tubular and indirectly heated and attached to said tubular structure at a position between said anode and the other end of said envelope remote from said collector, a post attached to one end of said tubular structure and engaging the collector, and mechanical means connecting the other end of said tubular structure to said other end of the envelope.

11. A magnetron comprising an anode having an annular interaction space therethrough, said anode including a plurality of sets of elongated parallel spaced segments, the segments of each set supported in a cylindrical interdigital array with the segments of the other set to define the outer periphery of the annular interaction space, an elongated non-emitting electrode coaxially disposed within the anode to define the inner periphery of the annular interaction space, an indirectly heated matrix-type tubular electron emitting cathode spaced axially from the interaction space, a control electrode surrounding the emitting cathode and defining therewith an annular transition space in axial alignment with the annular interaction space, and a collector electrode disposed on the side of the anode remote from the electron emitting cathode.

12. The combination according to claim 11, in which the control electrode is coaxially arranged about and extends in an axial direction beyond the ends of the cathode.

13. The combination according to claim 11, in which the non-emitting electrode coaxially disposed within the anode extends in an axial direction beyond the ends of the anode, the end portion of the electrode adjacent the cathode being spaced from the cathode and cooperating with said control electrode and cathode to define said transition space.

14. The combination according to claim 11, in which said non-emitting electrode is electrically insulated from said collector and electrically connected to said cathode so as to operate at the same potential therewith.

15. In a voltage tunable magnetron including an evacuated envelope hermetically closed at opposite ends by metallic end cap structures including a collector, an electrode support structure extending axially through the envelope between the end cap structures, said support structure including an elongated metallic sleeve supported at one end on one of said end cap structures, a unipotential indirectly heatable cathode surrounding said sleeve intermediate its ends in radially spaced relation thereto to provide an annular space therebetween, and a filamentary heater surrounding said sleeve and extending into the annular space between the cathode and sleeve.

16. The combination according to claim 15, in which a non-emitting tubular metallic electrode coaxially surrounds an end portion of the sleeve remote from the end thereof supported on the end cap structure.

17. The combination according to claim 15, in which said support structure includes a ceramic rod having one end engaging the collector and its other end engaging the elongated metallic sleeve.

18. The combination according to claim 15, in which said non-emitting electrode is supported on the elongated metallic sleeve and is electrically insulated from the collector.

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