April 18, 1939. W. DÄLLENBACH 2,154,758

ELECTRONIC TUBE

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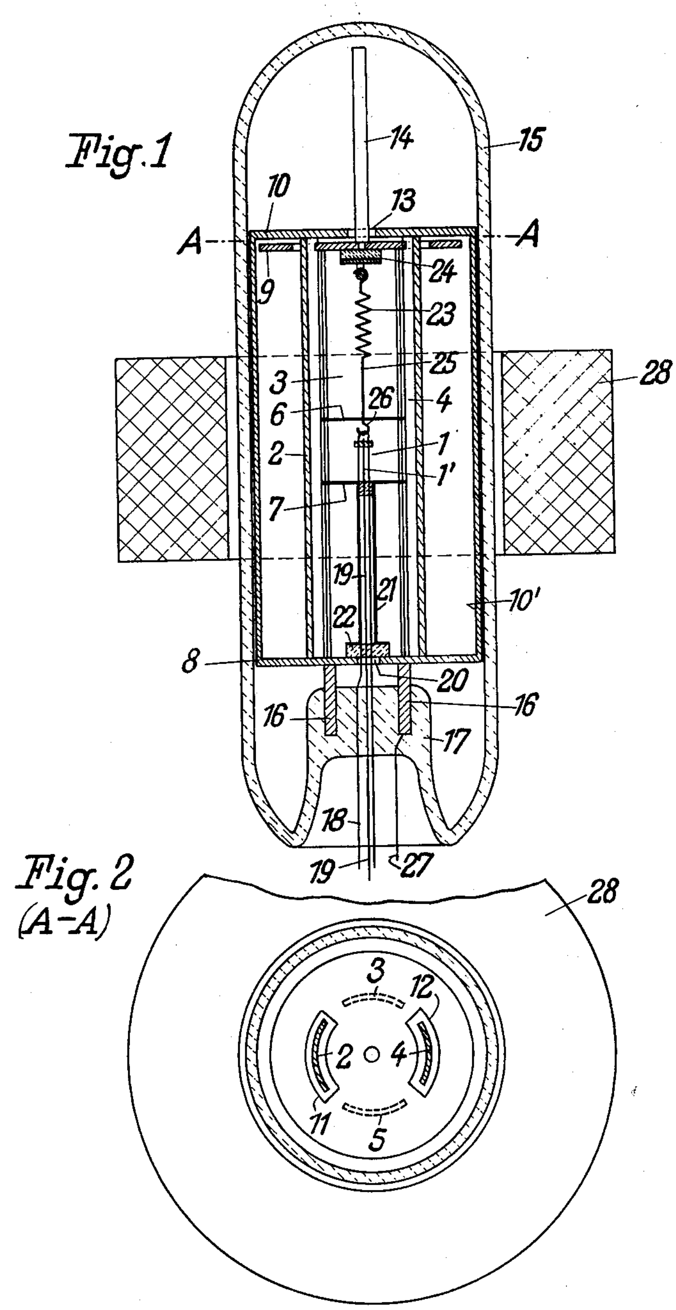

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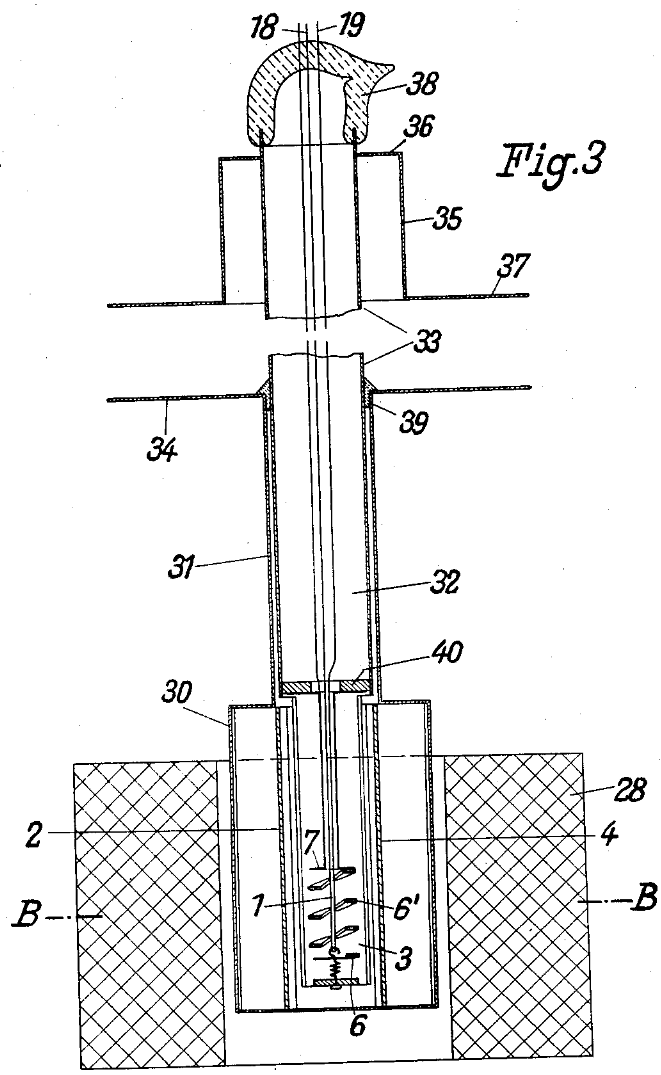

Fig. 3

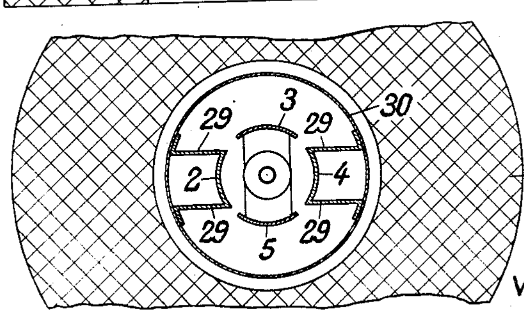

Fig. 4 (B-B)

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Fig. 5

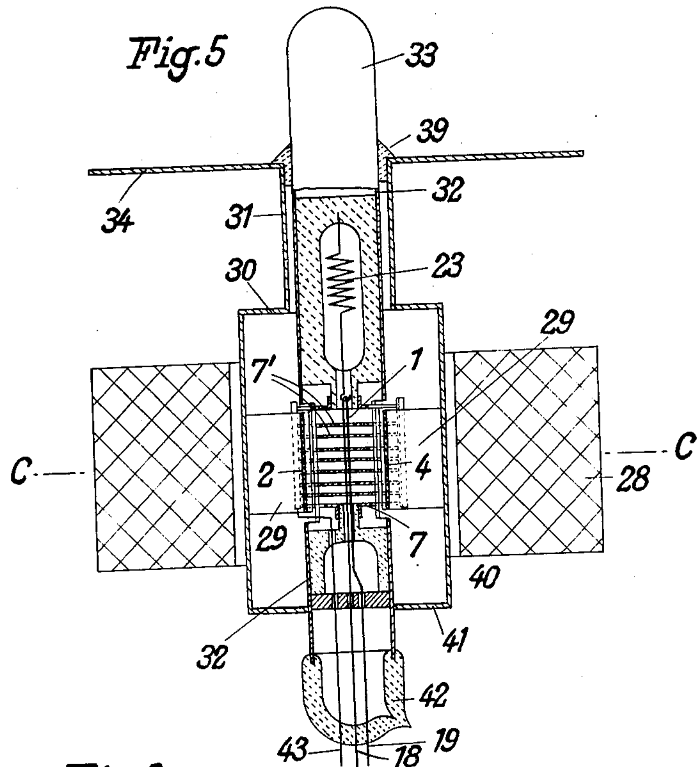

Fig. 6
(C-C)

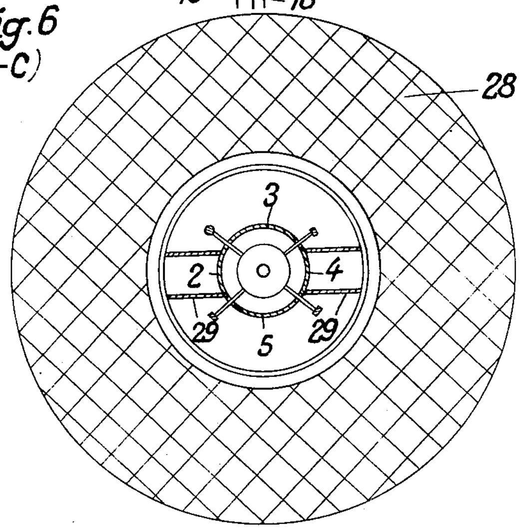

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Fig. 7

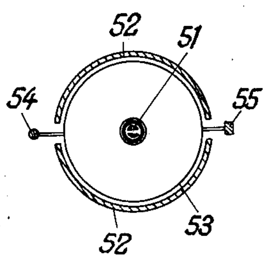


Fig. 8

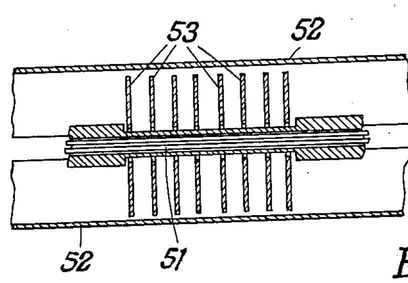


Fig. 15

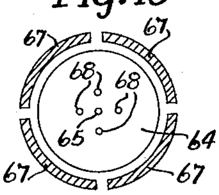


Fig. 9

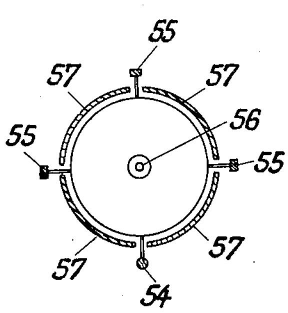


Fig. 10

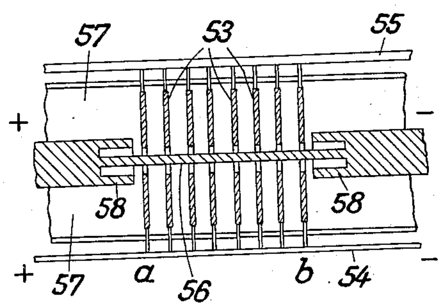


Fig. 11

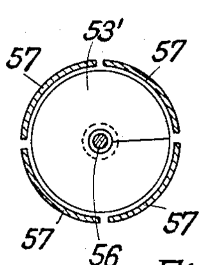


Fig. 12

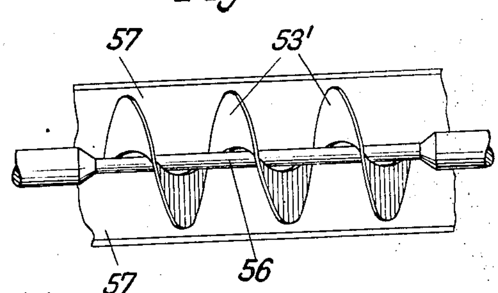


Fig. 13

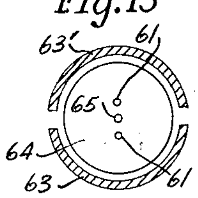
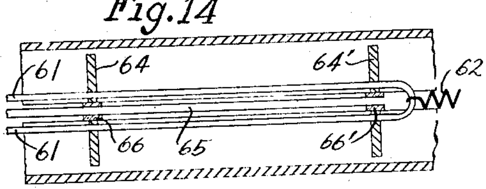


Fig. 14



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UNITED STATES PATENT OFFICE

2,154,758

ELECTRONIC TUBE

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Application February 26, 1936, Serial No. 65,881
In Germany February 28, 1935

13 Claims. (Cl. 250—27.5)

The present invention relates to magnetron tubes for exciting, and particularly for producing, amplifying or receiving ultra-high frequency electro-magnetic oscillations.

The tube according to the invention belongs to electronic tubes of the kind in which a so-called split anode is disposed around a cathode of rod or filamentary form, and in which the anode segments are components of an oscillatory circuit. As is known, such a tube can be excited into oscillation, that is to say can be used as a generator, amplifier or receiver, if a magnetic field, preferably constant and homogeneous, is effective perpendicular or approximately perpendicular to the stream of electrons passing between the cathode and the anode.

It is an object of the present invention to produce a magnetic field of maximum homogeneity in the discharge space of the tube, which is advantageously cylindrical.

It is another object of the present invention to avoid disturbing discharges at the ends of the discharge space.

It is a further object of the invention to enable the discharge, and thus the oscillations set up, to be controlled or modulated with the minimum distortion and without considerable consumption of power.

A further object of the invention is to provide a resonator with a small self-damping and with a high efficiency.

A still further object of the invention is to avoid diffuse or scattered radiation of the resonator and to couple the resonator in the most favourable manner to a loading resistance, e. g. to an aerial.

There is provided according to the invention a magnetron tube in which a split anode consisting of a plurality of segments and disposed about a cathode of rod or filamentary form is prolonged in the direction of the axis to constitute a resonator, and in which the discharge space surrounding the cathode is limited at the ends by conductive screens.

Examples of tubes in accordance with the invention are illustrated in the drawings annexed hereto.

Figure 1 is a longitudinal section through a magnetron tube in which the anode segments, of constant cross-section, are prolonged to a resonator of length $\lambda/2$, an aerial being coupled to one end of the resonator;

Figure 2 is a cross-section on line 2—2, Fig. 1;

Figure 3 is a longitudinal section of a magnetron tube having a cylindrical resonator which is limited by a vascular outer conductor and an inner conductor projecting into the latter;

Figure 4 is a cross-section on line 4—4, Fig. 3;

Figure 5 illustrates a magnetron tube having a resonator of length $\lambda/2$, which likewise is limited by a vascular outer conductor and a cylindrical inner conductor;

Figure 6 is a cross-section on line 6—6, Fig. 5;

Figures 7 to 12 are transverse or longitudinal sections illustrating more clearly than the previous figures electrode systems having a subdivided discharge space,

Figures 7 and 8 illustrating such a tube when an indirectly heated cathode is employed,

Figures 9 and 10 when a directly heated cathode is used, the voltage drop at the cathode being compensated, and

Figures 11 and 12 when a helix is used for subdividing the discharge space.

Figures 13 and 14 are transverse and longitudinal sections respectively of an electrode system having a hair-pin cathode and a filamentary control electrode.

Figure 15 shows in cross-section a similar electrode system having a double hair-pin or cage-like cathode consisting of four wires.

In the example illustrated in Figs. 1 and 2 of the drawings the electrode consists of a hair-pin like glowing cathode 1 and four hollow cylinder segments 2, 3, 4 and 5 disposed coaxially around the cathode and forming a split anode. The four anode segments are prolonged to form a resonator, their cross-section remaining constant. At the two ends the cylindrical discharge space is limited by metallic screens 6 and 7. A filamentary control electrode 1′ between the cathode wires serves to control the discharge. The extended anode segments are galvanically short-circuited at their lower ends by a metal plate 8 arranged perpendicularly to the axis of the system. At the upper end of the resonator two metal plates 9 and 10 are arranged at a small distance from one another and likewise perpendicular to the axis of the system. The anode segments 3 and 5 are galvanically connected to the plate 9. The segments 2 and 4 project through slots 11 and 12 provided in the plate 9 and are conductively connected to the plate 10. This latter plate has in its middle an opening 13 through which an aerial 14 attached to the plate 9 projects freely above the plate 10.

The resonator and aerial are disposed together in the vacuum vessel 15. For the purpose of securing the system comprising the electrodes, the resonator and the aerial in the tube the lower plate 8 is provided with metal supports 16 which are fused into the glass press 17. The heating leads 19 and the lead 18 for electrode 1′ are introduced into the resonator space through an opening 20 in the plate 8. Inside the resonator space, the heating leads are formed by the concentric conductors 19 and 21. The tubular conductor 21 is connected at its lower end to the lead-in wire 18 and is attached by the insulating member 22 to the plate 8. The conductor 21 carries at its upper end the screening plate 7 which limits the discharge space.

In order to impart to the hair-pin heating filament a suitable tension there is provided in the axis of, and in the upper part of the resonator a helical spring 23 the upper end of which is attached to the plate 9 through the intermediary of an insulating member 24. The lower end of the said spring is provided with a pull-wire 25 which engages by a hook 26 to the upper end of the cathode. There is also attached to the lower end of the wire 25 the other metallic screen 6 for bounding the discharge space. A suitable positive potential can be imparted to the anodes by a lead-in wire 27 conductively connected to one of the supports 16. The coil 28 serves to produce the coaxial magnetic field.

The arrangement functions in the following manner:—

With the positive potential at the anode segments suitably chosen and the strength of the magnetic field correctly adjusted thereto, when the cathode 1 is heated the stream of electrons set up in the discharge space is capable of undamping or exciting into oscillations the resonator consisting substantially of the four parallel conductors 2 to 5. The wave length of the oscillations produced by the resonator is then equal to twice the length of the resonator. A potential loop of the oscillations occurs in the middle, opposite the cathode, and potential nodes occur at the ends of the resonator, owing to the fact that the excitation takes place in the middle, while at the lower end the four anode segments are galvanically short-circuited by the plate 8 and at the upper end opposite anode segments are short-circuited galvanically the two pairs being short-circuited practically entirely capacitively by the two plates 9 and 10.

The space between the condenser plates 9 and 10 serves at the same time as an energy line for the optimum coupling of the aerial 14 to the resonator. It is possible by suitably selecting the distance apart of the two plates to adjust the coupling of the aerial to the resonator as desired. If the distance apart of the condenser plates 9 and 10 and thus the surge impedance of this energy line is made small, then in the neighbourhood of the opening 13 the alternating potentials exciting the aerial are only small, so that the aerial is only coupled loosely to the resonator. If the spacing of the plates is increased, the coupling of aerial and resonator becomes firmer. The aerial is advantageously tuned to a quarter of the wavelength of the oscillation.

The electronic tube illustrated may be varied in a large number of ways. Instead of using four anode segments as in the example above described, it is possible to use two, or more than four, but preferably an even number of like segments. Also the resonator can be of length $\lambda/4$, so that the discharge space is located at an open end thereof. Instead of an $\lambda/2$ or an $\lambda/4$ resonator, it is also possible to use one whose length amounts to $n.\lambda/2$ or $(2n-1).\lambda/4$ and which is thus excited in any harmonic vibration. In such cases it is also possible to arrange several cathodes in or near the potential loops.

In order to prevent loss radiation being emitted from the resonator the latter is surrounded by a metallic casing 10′ so that a hollow space is formed which is surrounded completely and on all sides by metal walls. Such a hollow resonator is characterised by a particularly small self-damping.

Further advantageous constructions of magnetron tube according to the invention with a hollow space as resonator are shown in Figs. 3–6.

Figs. 3 and 4 show a magnetron tube having a hollow space resonator of length $\lambda/4$. The electrode system is similar to that of Fig. 1. A hairpin cathode 1 is concentrically surrounded by four anode segments 2 to 5. The ends of the cylindrical discharge space are limited by metal plates 6 and 7. The discharge space is also subdivided by a control electrode in the form of a helix 6′. The anode segments are prolonged at their upper ends to the resonator of length $\lambda/4$. The even anode segments 2, 4 are connected through the intermediary of metal stays 29 to a hollow cylindrical metal housing or outer conductor 30 of the resonator. The odd anode segments 3, 5 merge into the inner conductor 32 near the transition of the metal vessel 30 into the neck 31 of the vessel. The concentric Lecher system formed by the neck 31 and the inner conductor 32 serves as an energy line for coupling an aerial 33 to the resonator. At its upper end the inner conductor merges into the aerial 33 without changing its cross-section. The neck 31 is provided at its upper end with a metal disc 34 which serves for the capacitive conduction of the aerial current.

The heating leads 18, 19 are introduced into the interior of the tube through the aerial which is formed as a hollow cylinder and through the hollow inner conductor 32 which adjoins said aerial. In order to prevent escape of oscillatory energy by way of the heating leads, the upper end of the aerial is equipped with a metal sleeve 35 which is conductively connected at its upper end to the aerial by the ring 36 and which carries at its lower end a metallic plate 37. A glass member 38 is fused to the upper end of the aerial, and the heating leads are introduced therethrough vacuum-tightly into the tube. The upper end of the energy line is likewise provided with a vacuum tight glass seal 39, so that the tube can be exhausted to a high vacuum without the employment of a special vacuum vessel. The metallic transverse partition 40 inside the hollow inner conductor 32 also serves to prevent leakage losses along the heating leads. Instead of this single partition a larger number may be provided. The coil 28 again serves to produce the co-axial magnetic field.

The manner in which this tube functions is obvious from what has been said above. If the correct conditions of operation are chosen and the resonator is undamped or excited into oscillations, a potential loop is set up at its lower end and a potential node at its upper end at the place of transition into the energy line. By suitably choosing the ratio of the two surge impedances of energy line and resonator the aerial can be coupled to the resonator so loosely that it constitutes an optimumly proportioned loading resistance. The length of the energy line is preferably $\lambda/4$ or an odd multiple thereof.

Figs. 5 and 6 show a similar construction to that of Figs. 3 and 4 except that it comprises a resonator of approximate length $\lambda/2$. The electrode system is similar to the preceding examples. In the construction of Figs. 5 and 6 the discharge is controlled by a screen 7' disposed coaxially around the cathode and which is connected externally of the discharge space with insulated supports and with lead-in wires. The resonator is formed in substance of the vessel-like metallic housing or outer conductor 30 with the vessel neck 31, and the cylindrical inner conductor 32 projecting through said neck into the interior of the said metallic housing. The inner conductor projects through the bottom 41 of the housing and is galvanically connected thereto. In this construction also the inner conductor forms with said neck an energy line and merges at its upper end into an aerial 33. Likewise the outer conductor 31 is provided with a metal plate 34 for capacitively transmitting the aerial current. The glass seal 39 at the upper end of the energy line serves as a vacuum-tight closure for the tube. A glass support 42 is vacuum-tightly attached to the lower end of the inner conductor 32, and through it the heating lead-in wires 18, 19 are passed into the tube. A further lead-in wire 43 leads to the lower screen 7. Since the latter is insulated from the cathode, being attached to the small insulating tube 44, it can be used to control the flow of electrons and in particular for modulating the oscillation set up. The metallic disc 40 inside the inner conductor again serves to prevent energy losses by conduction.

The anode segments do not extend over the entire length of the resonator of length $\lambda/2$, but only over the middle part thereof, and are made only slightly longer than the discharge space. In addition the even anode segments 2, 4 are again conductively connected to the inner wall of the outer conductor 30 by the connecting parts 29. The odd segments 3, 5 merge into the inner conductor at the ends of the discharge space.

If the tube is excited into oscillations a potential loop forms at the anode segments, while potential nodes form at the upper and lower ends of the resonator. In contrast to the construction of Figs. 3 and 4, the surge impedance is not constant over the entire length of the resonator, but is greater at the ends of the resonator than in the previous case. This increase in the impedance shortens the length of the resonator and reduces its natural or self damping. Of course, in this example also, instead of four anode segments, two or more than four may be provided, being connected alternately to the inner and outer conductors.

Figs. 7 and 8 illustrate an electrode system in which a rod-like indirectly heated cathode 51 is surrounded by a split anode composed of two segments 52. As in Fig. 5, thin insulated metallic screens 53 are disposed between the cathode and the anode at constant distances from one another and perpendicular to the axis of the electrode system. The screens 53 are connected by short stays to a common lead 54 situated outside the split anode. The insulating support 55, likewise disposed outside the split anode, serves, together with the lead 54, to hold the screens rigid within the rest of the electrode system. By using an equi-potential cathode the result is obtained that all the discharge spaces operate under like conditions. Thus, the same favourable bias can be imparted to the screens for all the compartments.

Figs. 9 and 10 illustrate a construction comprising a directly-heated cathode 56 and a split anode consisting of four segments 57. The conductive screens 53, in this case likewise, are conductively connected to a lead outside the split anode and are also attached to the insulating supports 55 disposed externally of the anode. If the lead 54 is made of suitable resistance material between the points a and b, then by applying a potential to both ends, just as by using an indirectly heated cathode, the result can be obtained that all the discharge spaces work under approximately similar conditions, and the most favourable bias can be adjusted for all the screens. In order to prevent emission of the cathode outside the discharge spaces limited by each two screens, the ends of the cathode are surrounded by cylindrical sleeves 58. Since the ends of the cathode emit less than the middle thereof owing to heat conduction, the length of the parts of the cathode running outside the discharge spaces can be made so great that there is approximately the same emission in all the discharge spaces, without a disturbing emission occurring at the ends.

In the construction illustrated in Figs. 11 and 12, as in the construction of Figs. 3 and 4, a controlling member 53' composed of a coherent helical surface is disposed between the cathode 56 and the split anode 57. This helix subdivides the discharge space, so that the control effect is increased. On account of the pitch, the helix is only approximately perpendicular to the axis of the arrangement, or to the direction of the magnetic field, but this has practically no effect upon the paths of the electrons.

In the construction of Figs. 13 and 14, 61 indicates a hair-pin cathode, which may be tensioned for instance at its right hand end in Fig. 14 by the helical spring 62. Concentrically around the cathode there is arranged a split anode consisting of two segments 63 and 63'. The discharge space used for exciting the oscillations is limited at its two ends by screens 64 and 64' disposed perpendicular to the axis of the tube. In the construction illustrated the screens are attached to the cathode wires. In the plane of symmetry between the two cathode wires there is provided a wire 65 serving as the control electrode and which is attached by insulators 66 and 66' to the discs 64 and 64'. Experiments have shown that the control effect of the axially disposed wire 65 is best when the cathode wires 61 are arranged displaced by 90° relative to the anode slits as shown in the figures.

Figure 15 is a cross-section of a tube having a four-part split anode 67 illustrating the most favourable arrangement of a cage-like cathode composed of four wires 68. Axially of the arrangement there is provided the filamentary control electrode 65. The cathode wires 68 are disposed symmetrically around and at a slight distance from the control electrode in such a manner that each wire is displaced by 90° relative to an anode slit. With this four-part arrangement one cathode wire and one slit may lie in each plane through the axis of the tube.

What I claim is:

1. A magnetron tube comprising a substantially cylindrical vacuum container, means for producing a magnetic field around said container, a split anode consisting of segments and a filamentary cathode disposed in said vacuum container, parallel to the longitudinal axis thereof, tubular segmental conductors joining said segments and extending substantially in the same axial direction of said container and forming with said segments an oscillator concentric with

said axis, and conductive screens limiting the discharge space between said cathode and anode.

2. A magnetron tube comprising a substantially cylindrical vacuum container, means for producing a magnetic field around said container, a split anode consisting of segments and a filamentary cathode disposed in said vacuum container, parallel to the longitudinal axis thereof, tubular segmental conductors joining said segments and extending substantially in the same axial direction of said container and forming with said segments an oscillator concentric with said axis, and a plurality of conductive screens limiting and subdividing the discharge space between said cathode and anode.

3. A magnetron tube comprising a substantially cylindrical vacuum container, means for producing a magnetic field around said container, a split anode consisting of segments and a cathode disposed in said vacuum container, parallel to the longitudinal axis thereof, conductors joining said segments substantially in the same axial direction of said container and forming with said segments an oscillator concentric with said axis, and a helical conductor subdividing the discharge space between said cathode and anode.

4. A magnetron tube substantially in accordance with claim 1, wherein said screens are conductively connected with said cathode.

5. A magnetron tube substantially in accordance with claim 1, comprising sleeves surrounding the ends of said cathode.

6. A magnetron tube as in claim 1, comprising insulators supporting said screens, and a lead connected to said screens.

7. A magnetron tube, comprising a substantially cylindrical vacuum container, a split anode consisting of segments and a cathode disposed in said vacuum container, parallel to the longitudinal axis thereof, tubular segmental conductors joining said segments and extending substantially in the same axial direction of said container and forming with said segments an oscillator concentric with said axis, a plurality of conductive screens subdividing the discharge space between said cathode and anode, and a magnet having a field substantially parallel to the electrode arrangement.

8. A magnetron tube substantially in accordance with claim 1, having a control electrode said control electrode lying within said discharge space.

9. A magnetron tube as in claim 1, comprising a metallic casing surrounding the oscillator.

10. A magnetron tube comprising a vacuum container, means for producing a magnetic field around said container, a cylindrical split anode consisting of an even number of segments, a cathode symmetrically disposed within said anode, conductive screens limiting the discharge space between said cathode and anode, conductors adjoined to both ends of said segments and extending in the axial direction of said container and forming with said segments an oscillator, a conductor galvanically connecting the said conductors of the oscillator at one end, a first condenser plate at the other end of said oscillator and connected to even-numbered conductors, a second condenser plate at the same end of said oscillator and connected to the odd-numbered conductors, said condenser plates forming a high frequency line at a small distance from, and preferably perpendicularly to the axis of, said oscillator, and an aerial connected to said first condenser plate and projecting through an opening in the second condenser plate.

11. A magnetron tube comprising a hollow cylindrical metal body, means for producing a magnetic field around said hollow body, an inner body coaxially arranged in said hollow body, a split anode consisting of an even number of segments coaxially arranged in said hollow body, a cathode within the split anode, the even-numbered segments being conductively connected to a wall of said hollow metal body, the odd-numbered segments being conductively connected at one end to said inner body, and the said hollow body and the inner body forming with said segments an oscillator.

12. A magnetron tube as in claim 11, said hollow metal body and said inner body forming a concentric high frequency line, the surge impedance of said high frequency line being small compared to the surge impedance of said oscillator, and vacuum seals in the annular gap of said high frequency line, the said hollow metal body forming a vacuum tight vessel.

13. A magnetron tube comprising a cylindrical hollow metal body closed at its ends, means for producing a magnetic field around said body, an inner body arranged coaxially within said hollow metal body, a split anode consisting of an even number of segments in the middle part of said hollow body, a cathode symmetrically disposed within said anode, the even-numbered segments being conductively connected to said hollow body and the odd-numbered segments being connected at both ends to said inner body, said hollow body and said inner body being conductively connected at one end and being spaced to form a high frequency line at their other end, said bodies forming an oscillator, and conductors for controlling the discharge between said cathode and anode.

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