Aug. 30, 1938. W. DÄLLENBACH 2,128,235

VACUUM DISCHARGE TUBE

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Fig.1

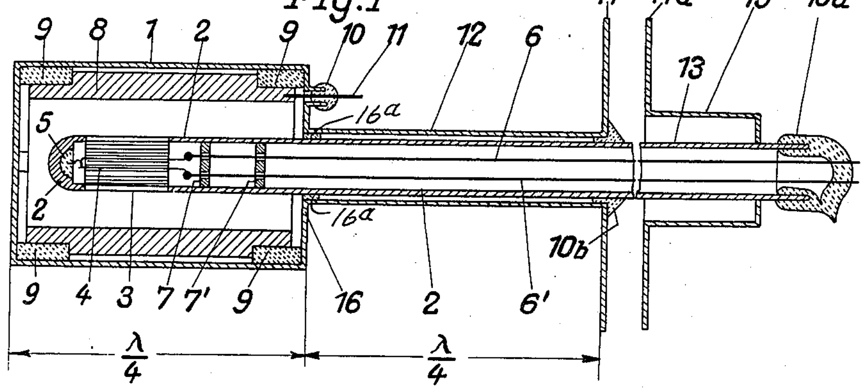


Fig.2

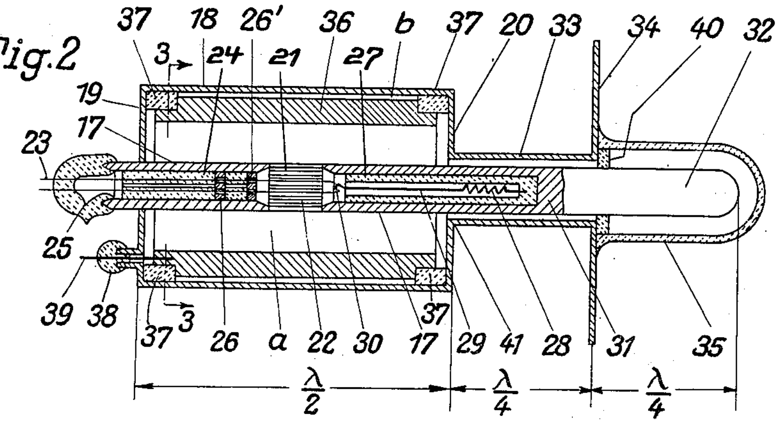


Fig.4

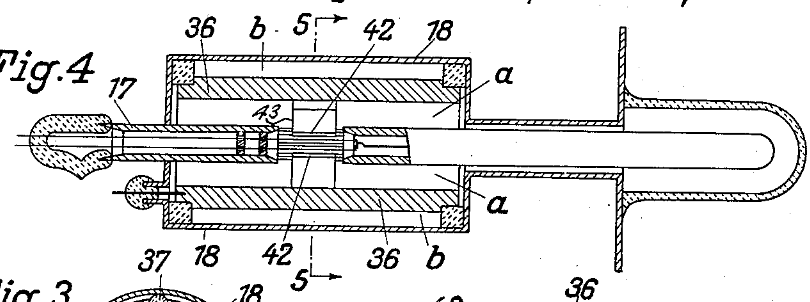


Fig.3

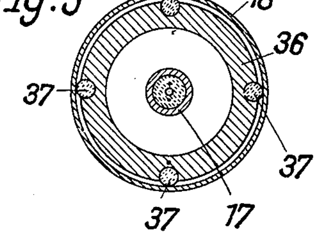
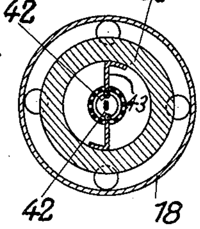


Fig.5



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2,128,235

VACUUM DISCHARGE TUBE

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10 Claims. (Cl. 250—27.5)

My invention relates to a vacuum discharge tube and particularly to a tube for exciting, i. e. for generating, amplifying and receiving ultra short-wave electro-magnetic oscillations.

With electron tubes for very short electromagnetic waves it is found necessary to join the electrodes, employed for excitation, immediately with the resonator. In order to obtain a resonator of low natural damping and with it, a tube of excellent efficiency, it is further essential, to keep the ohm's damping losses and, above all, the radiation losses of the resonator within narrow limits. Further requirements are: a proper escape of the heat from the electrodes for the purpose of avoiding inadmissibly high temperatures and secondly, a high degree of disruptive strength of the insulators between the electrodes, subjected to varying potentials, and the conductors connected therewith.

The abovementioned requirements are met with to a very high degree by the vacuum discharge tube described in the following. As resonator of the tube a hollow space is made to serve, limited all round by electrically well conducting walls; it not only exhibits merely very small ohm's losses, but also practically no radiation losses. In order to be able to excite this hollow space to oscillations, two or more than two electrodes are required, which either belong to the hollow body proper, limiting the hollow space, or which may also be disposed within or without the hollow body. Particularly advantageous constructions are yielded when placing at least one electrode (intermediate electrode) into the interior of the hollow body enclosing the hollow space of the resonator. For the purpose of securely attaching this electrode and insulating it from the walls of the hollow body, it is essential to support the electrode within the hollow body at suitable points by means of insulators. The insulators are advantageously disposed within potential nodes or at relatively cool points in the tube in order to obviate losses. For the same reason the leads to this intermediate electrode are so arranged, that they are passing through the field space of the resonator and the hollow body, encasing the resonator, in the proximity of potential nodes.

In a practical example of performance of the present invention, the body, encasing the field space of the resonator, is made to consist of two co-axial hollow metallic cylinders, an outer conductor and an inner conductor concentric thereto. The intermediate electrode will then suitably be made also of cylindrical shape and disposed co-axially between the two conductors. The inner conductor is provided at a suitable point with a grid, whilst in the interior of the grid a cathode is provided for the purpose of producing thermionics. In order to connect the resonator with a loading resistance, e. g. an aerial, without entailing radiation losses, the outer, as well as the inner conductor, are continued at least at one end, by a concentric high frequency transmission line. In accordance with an example of performance of the present invention, the other end of the outer conductor will then be closed up by a bottom plate, whilst the inner conductor is made to end freely in the proximity of this bottom plate. In accordance with a second example of performance the ends of the outer and the inner conductor, turned away from the high frequency transmission line, is galvanically connected. In all examples of performance the outer conductor essentially serves as vacuum vessel and has been rendered vacuum tight by means of glass fusings.

Further characteristic features of the present invention may be gathered from the following description and the drawing belonging thereto.

Fig. 1 represents in longitudinal section an ultra-short wave tube in which the field space of the resonator is limited by a bulb-shaped outer conductor and a conductor freely terminating in the proximity of the bottom of the vessel.

Fig. 2 illustrates in longitudinal section, and Fig. 3 in cross section, an ultra-short wave tube, in which the inner and the outer conductor have been galvanically connected with each other at one end.

Figs. 4 and 5, finally, show in longitudinal, and in cross section, respectively, an ultra-short wave tube similar to that shown in Figs. 2 and 3 with special control electrodes disposed between cathode and grid.

The tube as shown in Fig. 1 essentially consists of the bulb-like and cylindrically hollow metallic body **1** (outer conductor) and a concentric metallic cylinder **2** (inner conductor) freely terminating in the proximity of the bottom of the bulb. The inner conductor is hollow, being provided at its end with a grid **3** and with a hair-pin like cathode **4** disposed in the interior of the latter. The cathode has been attached to the end of the inner conductor **2** by means of an insulating body **5**. The two cathode leads **6**, **6'** are made to so pass through the inner conductor **2** as to be insulated therefrom. The two metallic rings **7**, **7'**, through which the cathode leads are passing, also being insulated therefrom, are limiting spaces in the interior of the grid electrode and the inner hollow conductor, said spaces being detuned relatively to the resonance space being excited.

Within the bulb-shaped hollow body 1 has been placed an electrode 8 (intermediate electrode), having the shape of a hollow cylinder, being supported by insulating bodies 9 at the faces within the hollow body, so that they are immovable in an axial, as well as in a radial direction. The intermediate electrode shown in the example of performance has been made only a little shorter than the cylindrical outer conductor 1, causing the cylindrical hollow space between the outer and the inner conductor to be sub-divided into two spaces communicating with each other at the ends by means of narrow slits. The diameter of the intermediate electrode is made to be so large, that between the inner conductor and the intermediate electrode a wide distance and between the intermediate electrode and the outer conductor a narrow distance is produced. In this way two resonance spaces of equal natural frequency, but of differently great surge impedance will be formed, being coupled with each other at the ends by the narrow annular slits. In the present case, the inner space between the conductors 2 and 6, serves as the resonance space proper, whilst the outer space between the conductors 1 and 8 is employed as short circuit condenser.

The right ends of the inner and of the outer conductor are continued by a concentric high frequency line 2, 12, the length of which is suitably made to equal a quarter of the wavelength or an odd multiple thereof. The inner conductor of the high frequency line is continued at the right end as conductor 13, also serving as aerial, whilst the outer conductor terminates in the metal plate 14 fitted perpendicularly to the axis of the tube and serving as a counter-poise to the aerial.

For the purpose of loosely coupling the aerial with the resonator, the distance between the conductors 2, 12 is made to be small when compared with the distance between the conductors limiting the resonator. The high frequency line, therefore, represents for the resonator almost a short-circuit condenser, so that at the point of junction between the two, a potential node of the oscillation is formed. At the left, open end of the resonator, on the other hand, a potential loop of the oscillation is formed, so that the total length of the resonator approximately agrees with the quarter wavelength or with an odd multiple thereof. In the proximity of the potential node, the intermediate electrode is provided with a lead 11, which so passes through the glass fusing 10 as to be vacuum-tight, being thereby insulated from the outer conductor 1.

In order to keep high frequency energy away from the cathode leads, a sleeve 15 has been passed over the extended aerial 13. The right end of the sleeve is galvanically connected with the right end of the aerial, whilst the left end is made to carry a plate 14*a* serving as counterpoise. The conductor 13 forms, together with the sleeve 15, a resonator which is tuned to the oscillation excited in the tube, emitting radiation in a radial direction only over the portion situated between the two disks 14 and 14*a*. The disks 14 and 14*a* serve for the capacitative transfer of the high frequency alternating current from the aerial to the outer conductor 12 of the high frequency line. The right end of the hollow conductor 13 is provided with a glass sleeve 10*a*, through which the cathode leads 6 and 6′ are so made to pass as to be vacuum-tight. For the purpose of rendering the tube vacuum-tight, the right end of the high frequency line is also provided with a glass fusing 10*b*. A separate vacuum vessel will then not be required. In order to highly evacuate the tube, the glass sleeve 10*a*, can be connected up with an air pump.

The tube may also be excited to oscillations in accordance with different connections. The mode of acting of the described arrangement, when employing the brake field connection, is as follows:

The inner conductor is given a high positive potential and the electrode 8, arranged so as to be insulated, an appropriate low positive or negative potential. By means of a corresponding heating of the hot cathode 4, the $\lambda/4$ resonator, being composed of the inner and outer conductor, can be excited to oscillations.

In the described case bulb 1 and with it, the outer conductor of the transmission line does not require to be given a special D. C. potential. At a suitable point, e. g. at the nodal point 16, a galvanic connection between the inner and the outer conductor may advantageously be provided, which can be done, for example, by making the part 16*a* between the inner conductor and the outer conductor of a metallic conductive material. The two conductors of the high frequency line will then be on the same D. C. potential.

Examples of performance of the present invention, still more advantageous, are represented by the Figs. 2–3 and 4–5. In this instance a resonator of the length $\gamma/2$ is used. In the ex ample as shown in Fig 2, the resonance space utilized for excitation, is essentially encased by the two concentric cylinders 17 and 18 which, together with the end faces 19, 20, are limiting a toroidal hollow space. The middle portion of the inner conductor forming a hollow cylinder has been replaced by the grid electrode 21, which is made to consist of tungsten molybdenum wire, extending parallel to the cylinder axis. Within this grid electrode, on the other hand, a hair-pin like cathode 22 has been housed, the leads 23 of which are extending through the insulating body 24 and the inner conductor being insulated from the latter. The inner conductor 17, being galvanically connected with the wall 19 and projecting beyond the latter, has been provided at the left end with a glass sleeve 25, through which the cathode leads are so passing, as to be vacuum tight. The two metallic rings 26, 26′ serve again for detuning the hollow space, containing the cathode, within the grid 21 or for forming further detuned spaces within the inner conductor 17.

The hair-pin like cathode 22 is given a suitable filar tension through the medium of the spiral spring 28. The spiral spring is situated within the insulating body 27 and attached with its right-hand end to the insulating body. It engages the cathode with its left end by means of the pull-wire 29 and the hook 30. The spiral spring is situated at a considerable distance from the hot cathode and the grid, the latter being highly heated during excitation in brake field connection, in order to avoid its elasticity being impaired in consequence of being heated.

The inner conductor 17 and the outer conductor 18 are continued at the right end in the form of a transmission line of the length $\gamma/4$. The inner conductor 31 is continued by a $\gamma/4$ aerial 32, whilst the outer conductor 33 terminates at the right end in a metal plate 34 fitted perpendicularly to the axis of the tube, said metal plate serving as counter poise. For the purpose of rendering the tube vacuum-tight, a short glass tube 35 is pushed over the aerial 32, said glass tube being fused together with the plate 34. In order to avoid a contact between the inner and the outer conductor with the high frequency line, the outer conductor 33 is advantageously provided at the right end and at the point it joins the metal disk 34, with a dielectric guide ring 40, consisting, e. g. of glass or mica. On the expansion of the inner conductor 17 or the grid 21 owing to heat, the inner conductor will be capable of moving within this guide. The change of tuning of the aerial, caused by the heat dilation, can be duly considered when constructing the tube.

In the interior of the toroidal hollow space formed between the two conductors 17 and 18, has been housed the intermediate electrode 36, enclosed all-round and designed as a hollow cylinder. The intermediate electrode is supported by insulators 37 at the faces of the cylindrical space. At the left face the hollow body is provided with a glass fusing 38, through which the current lead 39 is passing to the intermediate electrode.

The toroidal hollow space, enclosed by the cylinders 17, 18 and the faces 19 and 20, forms the resonator to be excited. It is sub-divided by the hollow, cylindrical electrode 36 into two spaces *a* and *b*, being coupled with each other at the faces 19 and 20 by means of annular slits.

The external diameter of the cylindrical electrode 36 is only a little smaller than the internal diameter of the outer jacket 18. The resonance space *b* is thereby given, compared with the resonance space *a*, a small surge impedance. Essentially frequency determining will, therefore, be only the hollow space *a*, whilst *b* forms the short circuit capacity for the transmission of the high frequency current from the inner face of 36 to the faces 19 and 20.

When exciting the resonator space *a* in the first harmonic, a potential loop will be formed in the middle portion at the position of the grid 21 and potential nodes at the ends of the cylindrical resonator space. The internal width between the plates 19 and 20 will then fairly accurately agree with the half wavelength of the excited oscillation. The insulators 37 provided for the support of the electrode 36, as well as the current lead 39, are thus situated in the proximity of a potential node of the oscillation, whereby di-electric and leakance losses have been avoided.

Fig. 3 conveys an idea of the support of the encased electrode 36 within the concentric hollow space. The electrode 36 possesses at several points milled grooves which are made to partly contain the insulators 37. In consequence thereof, the electrode 36 cannot change its position either in an axial, or in a radial direction.

In the tube illustrated in Fig. 4 the diameter of the electrode 36 has been so dimensioned, that two concentric cylindrical resonance spaces *a*, *b*, of approximately equal surge impedance, are produced, being coupled with each other in potential nodes at the faces of the Lecher system. The tube, further, shows additional control electrodes 42 within the grid anode space, which are galvanically connected with the electrode 36 by means of short conductors, i. e. short when compared to the wavelength as indicated, for example, by the parts 43 (Figs 4 and 5). The control potentials, presenting themselves in the middle portion of the electrode 36, will then produce in the grid anode space an additional control of the flow of electrons.

Electron tubes, embodying the characteristic features in accordance with the present invention, exhibit the following advantages: In view of the fact, that the resonator consists of a hollow space, being limited all round by metallic walls, no loss radiation can take place. The leakage of oscillation energy along the current leads of the completely closed electrode has been reduced to practically zero by transferring the leading-through point in the outer conductor and the connections with the intermediate electrode, to a potential node of the oscillation. Also the leakage of oscillation energy along the cathode leads have been avoided. The cathode is accommodated in one space which is strongly detuned relatively to the resonance space. The coupling of the resonance space with the cathode space existing above the grid interstices, cause there only quite inconsiderable potential amplitudes, so that also the heating wire can transmit only low A. C. potentials. As a result of the bifilar arrangement of the hot cathode and of the employment of a plurality of screens (26, 26'), closing up spaces within the hollow inner conductor 17 which are strongly detuned relatively to the resonator subjected to excitation, the leakance along the heating line has been reduced to zero.

It will, furthermore, be possible to attain the most favourable adaptation of the aerial to the tube by means of the dimensioning of the high frequency line, being carried out with relatively low surge impedance. Owing to the low surge impedance of the high frequency line, the potentials presenting themselves at the junction of high frequency line and aerial, are low, whilst the control potentials within the tube at the points of junction of the inserted electrodes, are high. The latter are principally decisive with regard to the high degree of efficiency of the tube. Further, in the tubes in accordance with the present invention, there will be no insulation difficulties in the high frequency line, because the walls of the line, separated by a narrow distance only, do not take a high opposing D. C. potential.

A separate vacuum vessel may also be omitted in the tubes in accordance with the present invention, because the metallic hollow body itself forms the vacuum vessel. In view of the fact, that the walls of the tube, connected with the electrodes are communicating with the outer space, an excellent cooling will be attained. The cooling of the tube will still further be improved by the fact, that the electrode, which is very considerably heated whilst in operation, (f. i. the grid electrode when exciting the tube in brake field connection), is conductively connected with the outer jacket. In this case a metal, having a high melting point, will be used for the grid bars, e. g. tungsten or molybdenum, and for the other wall parts of the hollow space, non-ferro magnetic metals of good heat conductivity, f. i. copper or silver.

What I claim, is:

1. A vacuum discharge tube comprising an evacuated, hermetically sealed, cup-shaped, hollow body electrically conductive all around its inner surface, an imperforate shell intermediate electrode in the evacuated hollow body, insulating members supporting the intermediate electrode in the hollow body, a lead to said intermediate electrode passing through the hollow body

and insulated therefrom, a cathode within the body and leads to the cathode extending into the interior of the body.

2. A vacuum discharge tube comprising an evacuated, hermetically sealed, hollow member electrically conductive all around its inner surface, a hollow conductor concentrically mounted in the hollow member, an intermediate electrode between the hollow member and conductor, insulating members supporting the intermediate electrode in the hollow body, a lead to said intermediate electrode passing through the hollow body and insulated therefrom, a cathode in the interior of the hollow conductor, said conductor being provided with openings, and leads to the cathode.

3. A vacuum discharge tube comprising an evacuated, hermetically sealed outer hollow cylinder body having its inner surface electrically conductive all around and closed off at one end, a second hollow cylinder mounted concentrically in the first, a cylindrical intermediate electrode coaxially mounted between the first two cylinders and only slightly shorter and of slightly less diameter than the outer hollow cylinder, insulating members at the ends of the intermediate electrode supporting it in the outer hollow cylinder and insulated therefrom, a cathode in the interior of the second hollow cylinder, said second cylinder being provided with openings, and leads to the cathode.

4. A vacuum discharge tube comprising an evacuated, hermetically sealed, hollow member electrically conductive all around its inner surface, a second hollow conductor concentrically mounted in the first, one end of the second conductor being spaced from the end of the first member, concentric high frequency leads connected to each of the other ends of the first and second conductors, a coaxial intermediate electrode mounted between said hollow member and said second conductor and being only slightly shorter than said first member, insulating members supporting the intermediate electrode in the first member, a lead to this electrode in the vicinity of a potential node and passing through the first member, a grid on the free end of the second conductor, a cathode within the grid, and leads to the cathode extending within the hollow second conductor.

5. A vacuum discharge tube, comprising an evacuated, hermetically sealed, cylindrical and bulb-shaped hollow body forming an outer conductor of approximately the length $(2n-1).\gamma/4$, where n is an integral member, and γ the wave length, said body being electrically conductive all over its inner face, an inner cylindrical hollow conductor situated concentrically within the outer conductor, one end of the inner conductor being spaced from the end of the bulb-shaped outer conductor, a concentric high frequency line of the length $(2n-1).\gamma/4$ joining the other ends of the outer and inner conductors, the surge impedance being lower than that of the space between the outer and inner conductors, a coaxial and cylindrical intermediate electrode situated between the outer and inner conductors and only a little shorter than the outer conductor located at a small distance from the outer conductor and at a larger distance from the inner conductor, the space limited by the outer conductor and the intermediate electrode forming a short-circuit condenser for the oscillations, insulating elements supporting the intermediate electrode within the outer conductor, a lead to this electrode passing through the hollow body in the proximity of a potential node, a grid on the free end of the inner conductor, a hair-pin like cathode coaxially situated within the grid, leads to the cathode extending within the hollow inner conductor, and vacuum-tight glass seals at the openings in the outer and inner conductors and between the outer and inner conductors.

6. A vacuum discharge tube, comprising an evacuated hermetically sealed bulb-shaped hollow outer conductor electrically conductive all around its inner face, a hollow inner conductor situated concentrically within the outer conductor, one end of the inner conductor being galvanically connected with the end of the bulb-shaped outer conductor, a concentric high frequency line joining the other ends of the outer and the inner conductors, a coaxial intermediate electrode between the outer and inner conductors and being only a litle shorter than the outer conductor, insulating elements supporting the intermediate electrode within the hollow outer conductor, a lead to this electrode passing through the outer conductor in the proximity of a potential node, a grid on the inner conductor, a cathode situated coaxially within the grid, and leads to the cathode within the hollow inner conductor.

7. A vacuum discharge tube, comprising an evacuated hermetically sealed cylindrical and bulb-shaped outer conductor of the length $n.\gamma/2$ where n is an integral number and γ the wave length, a cylindrical hollow inner conductor situated concentrically within the outer conductor, one end of the inner conductor being galvanically connected with the end of the bulb-shaped outer conductor, a concentric high frequency line of the length $(2n-1).\gamma/4$ joining the other ends of the outer and inner conductors, the surge impedance of the high frequency line being lower than that of the space between the outer and the inner conductors, a coaxial and cylindrical intermediate electrode only a little shorter than the outer conductor spaced a slight distance from the outer conductor and a greater distance from the inner conductor, the space limited by the outer conductor and the intermediate electrode forming a short-circuit condenser for the oscillations, insulating elements supporting the intermediate electrode within the outer conductor in the proximity of potential nodes, a lead to this electrode passing through the outer conductor in the proximity of a potential node, a grid on the inner conductor at the distance of $(2n-1).\gamma/4$ from the end of the resonator, a hair-pin like cathode situated coaxially in the grid, leads to the cathode within the hollow inner conductor, said leads leaving the inner conductor at that end which is connected with the outer conductor, vacuum-tight glass seals at the openings in the outer and inner conductors and between the outer and inner conductors.

8. A vacuum discharge tube, comprising an evacuated hermetically sealed, cylindrical and bulb-shaped outer conductor of the length $\lambda/2$ where λ is the wave length, said outer conductor being electrically conductive all around its inner face, a cylindrical hollow inner conductor situated concentrically within the outer conductor, one end of the inner conductor being galvanically connected with the end of the bulb-shaped outer conductor, a concentric high frequency line of the length $\lambda/4$ joining the other ends of the outer and inner conductors, the surge impedance of the high frequency line being lower than that of the space between the outer and the

inner conductors, a coaxial and cylindrical intermediate electrode only a little shorter than the outer conductor spaced a small distance from the outer conductor and a greater distance from the inner conductor, the space limited by the outer conductor and the intermediate electrode forming a short-circuit condenser for the oscillations, insulating elements supporting the intermediate electrode within the outer conductor in the proximity of potential nodes, a lead to this electrode passing through the outer conductor in the proximity of a potential node, a grid in the middle portion of the inner conductor, a hair-pin like cathode coaxial within the grid, leads to the cathode within the hollow inner conductor, said leads leaving the inner conductor at that end which is connected with the outer conductor, insulating elements within the hollow inner conductor and metal discs for detuning the grid cathode space, a spring within the interior of the inner conductor, a pull-wire connected to the spring and a hook connected to the wire and cathode for putting the cathode under tension, vacuum-tight glass seals at the opening in the outer and inner conductors and between the outer and inner conductors.

9. A vacuum discharge tube in accordance with claim 2, with a control electrode between cathode and inner conductor, and conductors connecting this control electrode with the intermediate electrode.

10. A vacuum discharge tube according to claim 1, wherein the inner surfaces of said electrode are formed of non-ferromagnetic good conductive material, the leads thereto being of a material having a high melting point, and the conductors connected therewith, of material having good heat conductive properties.

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