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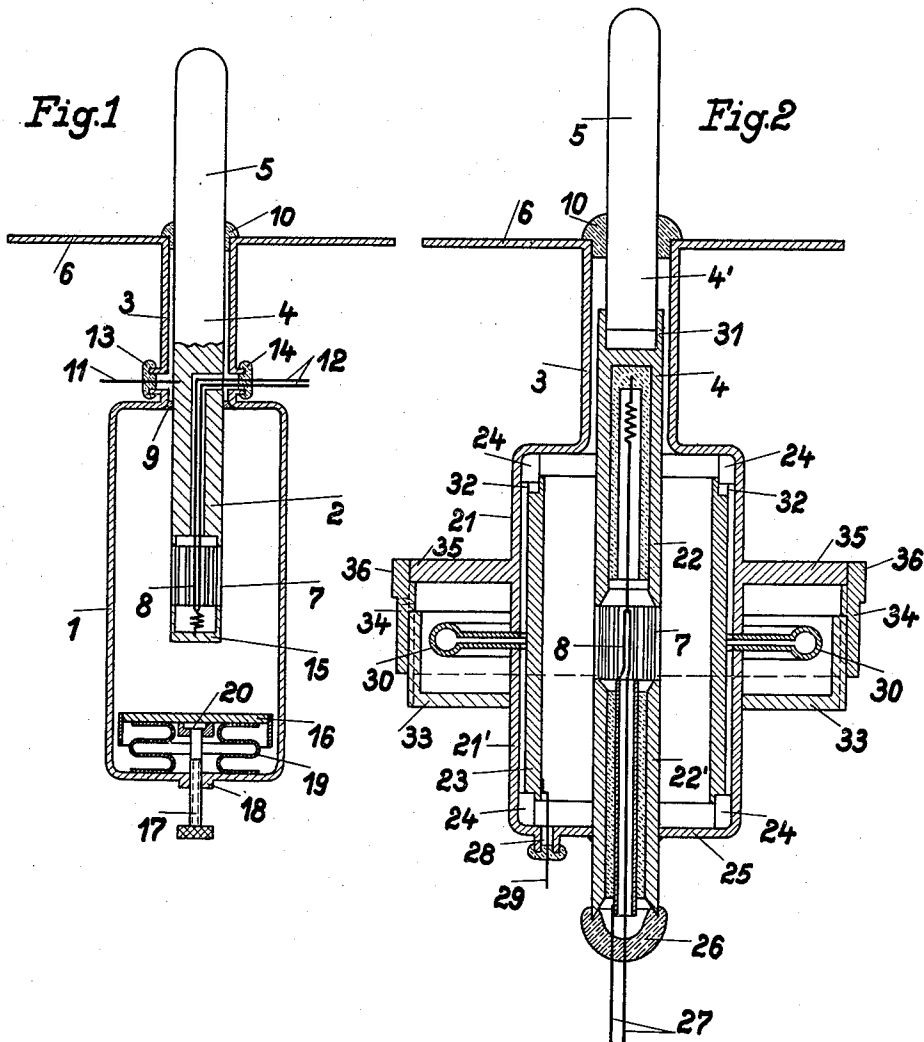
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2,167,201

ELECTRON TUBE

Filed June 22, 1936

4 Sheets-Sheet 1



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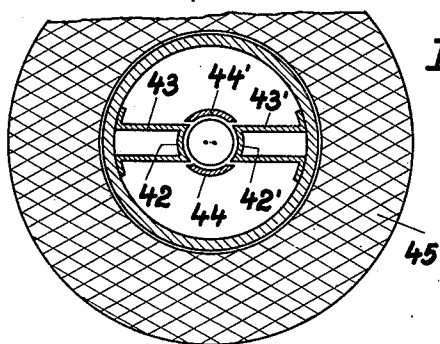
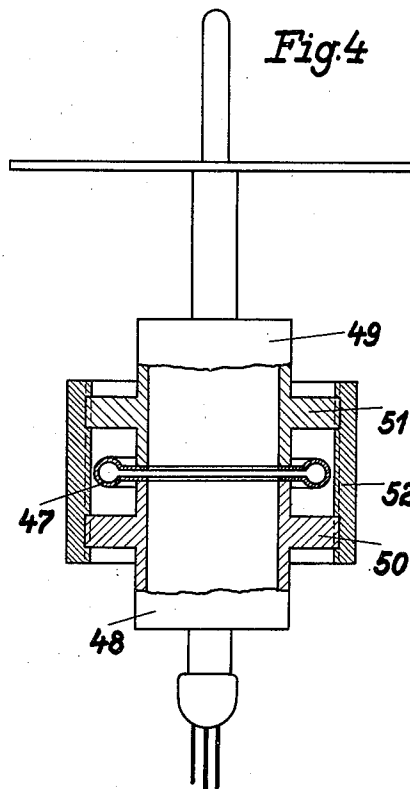
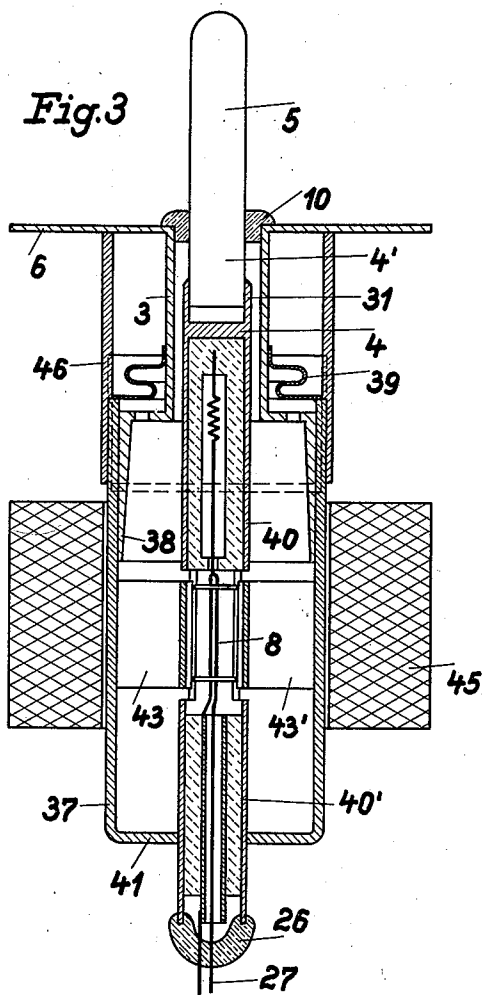
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ELECTRON TUBE

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4 Sheets-Sheet 2



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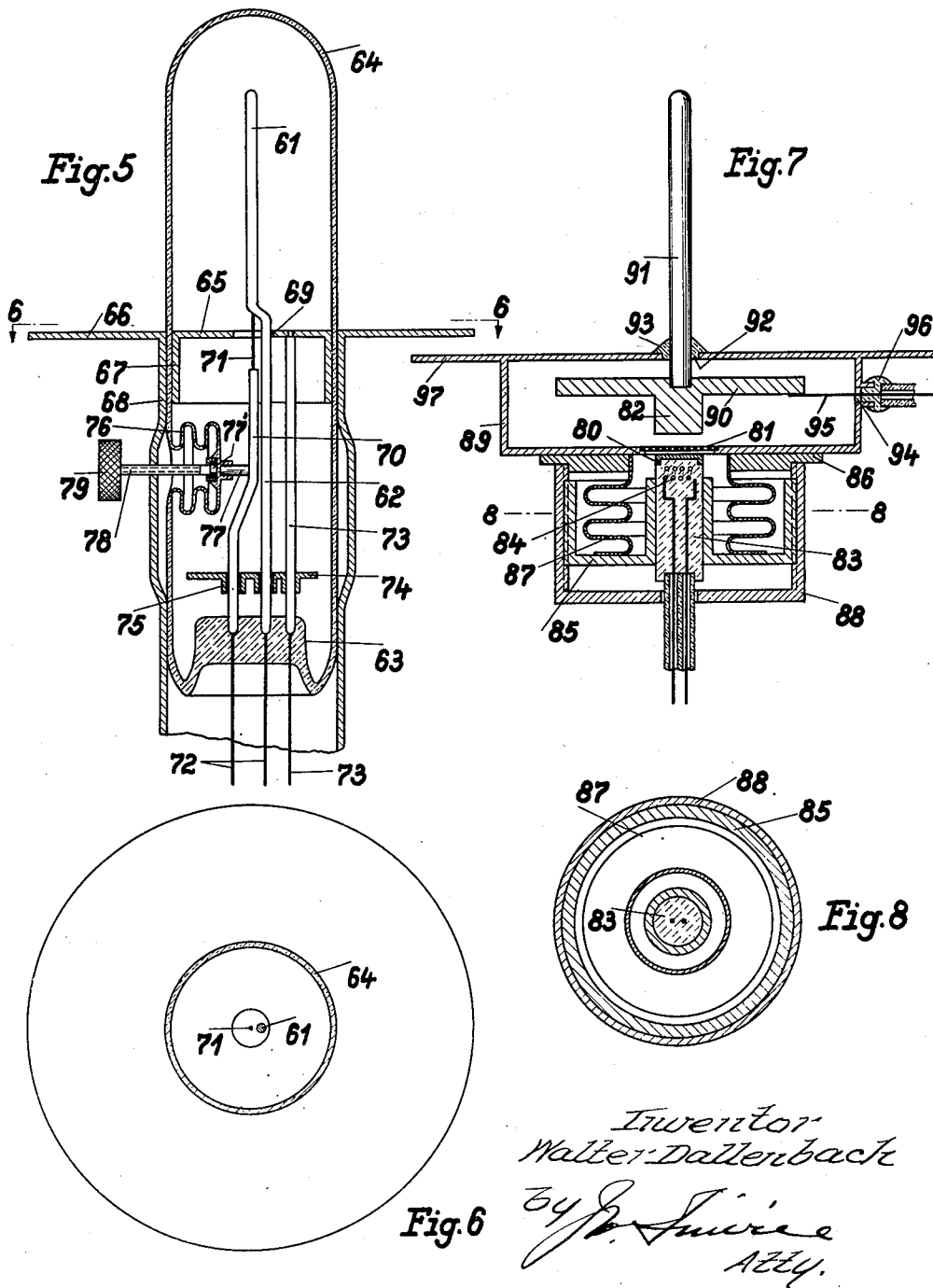
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ELECTRON TUBE

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4 Sheets-Sheet 3



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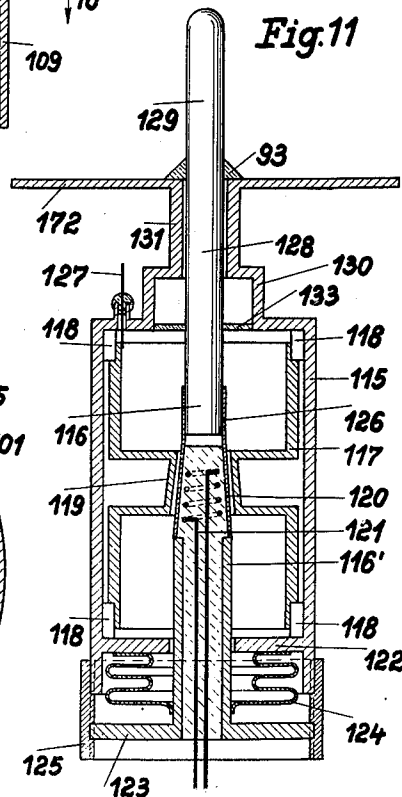
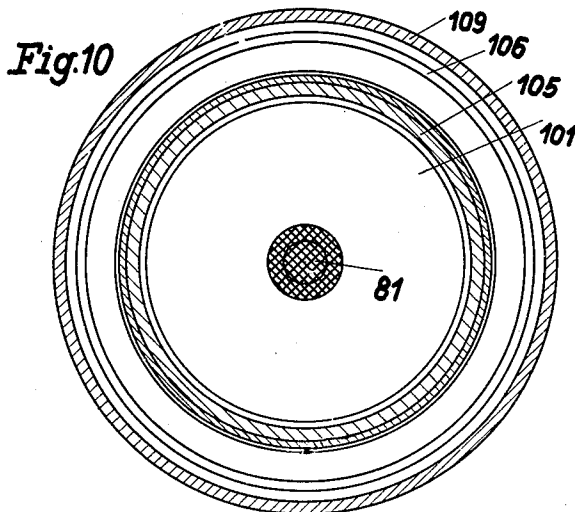
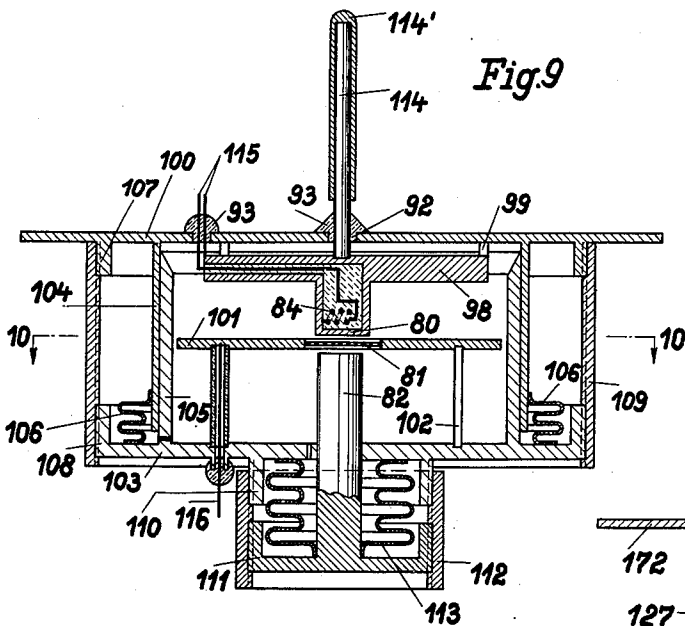
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ELECTRON TUBE

Filed June 22, 1936

4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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ELECTRON TUBE

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In Germany June 28, 1935

6 Claims. (Cl. 250—27.5)

The present invention relates to an electron tube for producing, i. e., generating, amplifying, or receiving ultra-high-frequency electromagnetic oscillations, and particularly to such an electron tube with a resonator formed as a chamber.

The subject-matter of the invention is an improvement in these tubes preferably such that they are made so that they can be tuned in relation to the proper frequency of the resonator.

As is known, in the case of the electrode tubes for producing ultra-high-frequency oscillations, the frequency is determined essentially by the geometric or electrical dimensions of the tube system, in contra-distinction to the arrangements for long electromagnetic waves, in the case of which the frequency determination is effected almost always by the oscillatory circuits located outside the tubes. In the case of long-wave arrangements, the tuning, for example of transmitters and receivers, can consequently take place in a simple manner by varying the external tuning means, whereas on the contrary the tuning in the case of ultra-short-wave arrangements cannot usually be effected in this manner.

Now by the invention a possibility is given of effecting the tuning by variations in the ultra-short-wave tube itself. As will appear from what follows, this may be of particular value in many cases. In order, for example, to enable exchange of information to be effected with the ultra-short-wave tubes mentioned in the beginning having a chamber resonator in which the electrodes can be placed at least partly in a nearly closed chamber, which can preferably be tuned to $\lambda/2$, the working frequency of the resonators must agree very accurately. Since the tubes are frequently set up in the open air, they are subjected to considerable variations of temperature, which cause small variations of the dimensions of the tubes and consequently variations of frequency. In addition there is the fact that the frequency alterations of the resonator producible in the case of braking field connection and magnetron connection through the alteration of the working conditions, as potentials, emissions, magnetic field strengths, become very small on account of the extremely small natural damping of the chamber resonators, so that a compensation of these variations of frequency is not possible by means of the working conditions.

Fig. 1 shows a so-called bottle tube with the arrangement according to the invention.

Fig. 2 shows a tube in which the hollow body bounding the chamber of small natural damping

surrounds an electrode that is wholly contained in its interior.

Figs. 3 and 3a show a tube with a chamber resonator which serves for igniting in the magnetron connection.

Fig. 4 shows a special micrometer arrangement.

Figs. 5-11 show arrangements in which the tuning is effected by varying the distance apart of electrodes.

In the case of the tube shown in Fig. 1 the chamber resonator is bounded by the vessel-like and cylindrical external conductor 1 and the internal conductor 2 co-axial therewith which together form a concentric Lecher system of the length $\lambda/4$ with a potential anti-node at the lower end and a potential node at the upper end. From the upper end extends a concentric high-frequency conducting device of the length $\lambda/4$, which forms an extension of the external and internal conductors and consists of an external conductor 3 and an internal conductor 4. The internal conductor 4 merges without cross-sectional variation into the $\lambda/4$ antenna 5. To the external conductor 3 there is connected a metal plate 6 which is at right angles to the axis of the tube and which serves for the capacitive transmission of the antenna current. The lower end of the internal conductor 2 is provided with a grid 7, which contains in its interior a hair-pin-shaped cathode 8. The conductor consisting of the sections 2, 4, 5 is supported against the bottle-like casing of the tube by the insulating rings 9 and 10. The insulating ring 9 is moreover made as a vacuum-tight glass fusion joint. As a potential node of the oscillations is formed at the place of transition between the chamber resonator and the high-frequency conducting device, the leads 11 and 12 pertaining to the grid electrode and the cathode are there introduced into the tube through openings in the casing of the tube. These openings are also likewise closed in a vacuum-tight manner by means of glass fusion joints 13, 14.

The variation of the wave-length of the resonator is effected, in the case of the example shown, by varying the terminal capacity between the bottom of the tube and the internal conductor. The portion of the bottom 16 of the tube that is opposite to the end of the internal conductor 15 is movable micrometrically in the axial direction by means of the screw 17 and the thread provided in the casing 1. For the purpose of vacuum-tight closure, the movable

portion of the bottom 16 of the tube is connected with the casing of the tube by a yielding wall.

The mode of operation of the tube is as follows: When the plate 16 approaches the internal conductor it increases the terminal capacity and consequently the proper frequency of the resonator diminishes. The effective air pressure in the axial direction on the plate 16 is transmitted to the micrometer screws between 17 and 18 through the screw foot 20. The plate 16 is guided at the edge in the casing 1. By the action of the external air-pressure there is thus produced a relatively rigid connection of the mutually adjustable parts, so that frequency variations during the working of the tube are avoided. Instead of a $\lambda/4$ resonator, a resonator of the length $(2n-1)\lambda/4$ may of course be provided with the micrometer arrangement hereinbefore described.

In the tube shown in Fig. 2 the hollow body bounding the resonator consists likewise of a vessel-shaped and cylindrical external conductor 21, 21' and an internal conductor 22, 22' co-axial therewith, which in this case form a concentric Lecher system of the length $\lambda/2$. A concentric high-frequency conducting device of the length $\lambda/4$ adjoins the upper end of the resonator in a manner similar to that of Fig. 1, consisting of an external conductor 3 and an internal conductor 4, 4'. The portion 4' of the internal conductor merges again into $\lambda/4$ antenna 5 and the external conductor 3 into the metal plate 6 perpendicular to the axis of the tube. The middle portion of the conductor 22, 22' is provided with a grid 7 which again carries co-axially in its interior a hairpin-shaped cathode 8. Between the external conductor 21, 21' and the internal conductor 22, 22' there is a cylindrical electrode 23, which is supported against the external conductor by insulators 24. The two parts 21' and 22' of the external and internal conductors are connected together galvanically at the lower end by a plate 25. The internal conductor 22' extends through this plate 25 and is provided at its end with a glass tube 26 through which the cathode leads 27 are led in a vacuum-tight manner into the interior of the conductor 22'. In order to enable a bias to be given to the electrode 23 in the interior of the toroidal resonator chamber, the plate 25 is provided with an opening 28 through which a lead 29 is led so as to be insulated into the interior of the tube. The opening 28 is closed in a vacuum-tight manner by a glass fusion joint, as is also the upper end of the high-frequency conducting device.

By the electrode 23, which is completely surrounded by the casing of the tube, the toroidal chamber between the conductors 21, 21' and 22, 22' is divided into two chambers, the space between the electrode 23 and the internal conductor forming the resonator chamber proper and the chamber between the electrode 23 and the external conductor serving as a short-circuit condenser for the resonator. In the case of suitable potentials at the electrodes, in particular in the case of a high positive potential at the grid 7 with a negative potential at the surrounded electrode 23 and with suitable emission of the hot cathode, the toroidal chamber resonator is caused to produce oscillations between the conductors 22, 22' and the surrounded electrode 23, a potential anti-node being formed in the middle portion and potential nodes of the oscillations at the upper and lower ends.

Since the wave-length of the oscillations pro-

duced depends on the length of the chamber resonator, and indeed in the present case is equal to double the length of the chamber resonator, its proper frequency can be varied by varying this length. The external conductor of the resonator consists therefore of two parts 21, 21', which are connected together in a vacuum-tight manner by means of the elastic wall 30 which is provided in the middle. The two sections 21 and 21' are consequently capable of being moved slightly in relation to each other in the direction of the axis of the tube. Since the internal conductor is connected rigidly with the upper part of the casing at the glass fusion joint 10 and is connected rigidly with the lower part of the casing by the metal plate 25, this must also consist of two parts which may be connected together conductively either by an elastic wall or by a trombone telescopic device. In the example shown, the internal conductor of the tube is provided with a trombone telescopic device, and, for the purpose of injuriously affecting the course of the oscillation process as little as possible, this is placed at the upper end of the high-frequency conducting device and consequently in the neighborhood of the potential anti-node. The part 4 of the internal conductor of the high-frequency conducting device is formed at the upper end as a tube 31. In this tube can move the part 4', which is made with a somewhat smaller cross-section. Now in order that the electrode 23 may present no resistance to the relative movement of the two parts of the tube, it is provided with milled recesses 32 in which the insulators 24 connected with upper part of the casing can move in the direction of the axis of the tube. Both the trombone telescopic device of the internal conductor and the yielding wall in the casing of the tube affect the electrical properties of the resonator approximately not at all. In particular, no injury is caused by the unavoidable separating gap between the two parts 21 and 21' of the external conductor, because that gap is located at the potential anti-node of the short-circuit condenser between the external and the enclosed electrode.

The micrometer arrangement consists of the cylindrical part 33 provided with a thread and fastened to the lower section of the tube, the part 34 provided with a counter-thread, and the part 35 connected with the upper section of the tube. The micrometer arrangement encloses the elastic wall 30 completely. The effective air pressure between the two sections of the tube is received by the micrometer arrangement. By the cylindrical and co-axial construction of the micrometer arrangement about the tube it is brought about that rotation of the micrometer part 34 results only in a movement of the parts of the tube in the direction of the tube axis. This is assisted by the provision of a guide 36 between the part 35 and the movable part 34. Consequently the air pressure presses the upper part of the tube with considerable force in this guide so that relative movements of the two parts are avoided. On rotating the movable part 34 in one direction the two sections of the tube are moved apart against the external air pressure and the frequency of the resonator is thereby reduced. In the case of the opposite direction of rotation, the return is effected by the air-pressure itself. In the same way, of course, generally resonators of the length $n\lambda/2$ can be made variable as respects their proper frequency by the same or a similar arrangement.

In the case of the tube shown in Figs. 3 and 3a the resonator consists, quite similarly to the example shown in Fig. 2, of a concentric Lecher system which is galvanically or capacitively short-circuited at the ends and which is ignited in the middle by means of an electronic stream. In the case of this example the casing of the tube consists essentially of the cylindrical part 37 and the part 38 which projects into the part 37 in the form of a piston. The two parts are connected together in a vacuum-tight manner at the upper end of the resonator by an elastic wall 39. The internal conductor consisting essentially of the two parts 40 and 40' is galvanically connected at the lower end with the casing 37 of the tube by means of the wall 41. The upper end of the internal conductor 40 is continued, as in the case of the example shown in Fig. 2, to the internal conductor 4, 4' of the high-frequency conducting device, which merges in the hollow-cylindrical part 31, in which the part 4 is movable after the manner of a trombone telescopic piece. The part 4' merges into the $\lambda/4$ antenna 5 and the external conductor 3 of the high-frequency conducting device provided with the upper piston-shaped part 38 of the casing is closed by the metal plate 6. The end of the high-frequency conducting device is again closed in a vacuum-tight manner by a glass fusion joint 10. For ignition there serves the hairpin-shaped cathode 8, which is surrounded by a four-part split anode. The two anode segments 42, 42' are connected with the casing 37 through pole-shoe like connecting parts 43 and 43'. The two other anode segments 44, 44' are galvanically connected with the internal conductor 40, 40' at the two ends. The field coil 45 serves for producing the co-axial magnetic field.

With such an electrode system oscillations are produced when the working conditions are suitably chosen. The proper frequency of the produced oscillations depends, exactly as in the case of the example shown in Fig. 2, on the length of the resonance chamber. Now this length can, as may be seen from the drawings, be varied in consequence of the elastic wall 39 and the trombone telescopic device 31. For the purpose of taking up the forces arising from the air pressure between the parts of the tube that are movable in relation to one another and for the purpose of producing the adjustment micrometrically, a micrometer arrangement is connected with the tube in this case also. The upper cylindrical casing 37 in fact is provided with a screw-thread on which can be screwed the tubular part 46 which is provided with a counter-thread. The upper end of the tube 46 engages the lower surface of the metal plate 6 which is rigidly connected with the piston 38 through the external conductor 3. The telescopic device provided between the conductors 37 and 38 or 4 and 4' can be adjusted by rotating the tube 46. The electrical properties are unaffected in this case also because the lower end of the piston 38 and the telescopic device are placed in the potential antinode occurring in the middle portion of the tube and at 31 in the neighbourhood of the potential antinode of the high-frequency conducting device respectively.

The micrometer arrangements connected with the tubes enable the proper frequency of the chamber resonators to be varied constantly at a given interval. Consequently not only can frequency variations consequent on temperature variations be thereby compensated for accurately,

but these tubes are also capable of use within a definite range of frequencies especially as transmitters or receivers. Consequently for example the same receiving tubes may be used for the reception of the signals of several transmitters with different proper frequencies.

Advantageously the adjustment of the resonator is made very fine. A micrometer arrangement that enables a specially fine adjustment to be made is shown in Fig. 4 in combination with a tube, which is represented only diagrammatically. The parts 48 and 49 of the tube connected by the elastic wall part 47 are provided with rings 50 and 51 which are both provided with left-hand or right-hand threads with slightly differing pitch. The cylinder 52 carries the corresponding counter thread. The adjustment is then equal to the difference of the pitches.

The application of the principle according to the invention is not limited to the constructional examples shown. In particular the arrangements described may be employed in the case of tubes which comprise, in addition to an igniting resonator, other resonators for controlling or for coupling. The proper frequency of these further resonators can be varied by means of the same or by means of supplementary arrangements. Thus, the inventional idea may be used for example in the case of a tube with a control resonator and with an igniting resonator and also in the case of a tube in which coupling channels and control chambers of resonance length are provided. Also, the inventional idea may be advantageously applied in the case of a tube which is provided with a chamber resonator for producing oscillations with greater wave length. In that case the walls of the external and internal conductors that are turned towards one another form a single-turn toroidal self-induction device, a concentrated capacity device, and electrodes in the neighbourhood of the concentrated capacity device. The variation of the proper frequency of the resonator may in that case be specially efficiently effected by the variation of the concentrated capacity device.

When dissonance is to be produced, as is also proposed according to the invention, by varying the distance apart of the electrodes, there are provided arrangements such as are shown for example in the following figures.

Figs. 5 and 6 show in elevation and plan and in section a constructional example of the invention which is especially suitable for receiving or for rectifying ultra-high-frequency oscillations. Here it is a question of the employment of a variable discharge path in the potential nodes between conductors of a resonator. The resonator consists essentially of the $\lambda/4$ rod antenna 61 which has as a continuation the conductor 62 and is carried by the pinch 63 of the tube. The horizon or the counter balance for the antenna is formed by the metal plate 65 which is arranged at right angles to the antenna and has as a continuation outside the vacuum vessel the annular part 66. At the place of division between 65 and 66 the two conductors are continued downwards by cylindrical parts 67, 68, which, with the wall of the vacuum vessel as a dielectric, form a short-circuit condenser and are advantageously cemented for the purpose of fastening the plates 65 and 66 to the wall of the vacuum vessel. The plate 65 is provided in the middle with an opening 69 through which the antenna 61 extends so as to be insulated. The antenna has a bend at a small distance from the plate. Between this

bend and the end of the conductor 70 there is, further, stretched a thread-like-cathode, in particular an oxide cathode 71, which can be heated through the leads 72. The plate 65 is also provided with a lead 73. The adjustable and approximately punctiform discharge path lies accordingly between the thread-like cathode 71 and the edge of the opening 69. For rendering dissonant the three leads 62, 70, 73 below the plate 65 there serves the plate 74 which is preferably arranged at a distance of the quarter wave length in from the plate 65 and which is provided with cylindrical conductors 75. At least two of the cylindrical conductors 75 are insulated from the leads and form with them short-circuit condensers for the purpose of preventing oscillation energy from escaping.

The adjustment of the discharge path is effected mechanically by bending the conductor 70. For this purpose there is fused to the vacuum vessel 65 a corrugated tube 76 of glass the bottom of which is connected with the conductor 70 within the tube through the intermediate piece 77. Outside the vacuum vessel there is connected with the bottom of the corrugated tube a guide 77' which is engaged by the screw 78. The screw 78 can be turned in this guide and in the thread in the cylindrical casing 68, which surrounds the lower portion of the tube. By rotating the screw knob 79 the conductor 70 can accordingly be bent laterally within certain limits and thereby there is produced a variation of the distance of the cathode 71 from the edge of the opening 69, preferably within distances apart between 0.1 and 0.01 mm. If, now, the hot cathode 71 is heated and a very small distance is produced between the cathode and the plate 65, there may occur, on the impingement of oscillations on the antenna 61, alternating potentials at the punctiform discharge path whereby is produced a transference of current and consequently a rectification. The direct current produced can be measured by a sensitive instrument placed between the leads 72 and 73. Working is advantageously effected at places of great sensitivity, i. e., at the end of the space-charge characteristic. For the purpose of determining this working point of maximum sensitivity the electrode 65 may be given a weak and preferably positive bias.

In the case of the constructional example shown in Figs. 7 and 8 the variable discharge space co-operates with a resonator of small proper damping and in fact with a resonator formed as a chamber. The arrangement made can then be used both for transmitting and also for receiving or amplifying ultra-high-frequency oscillations. There is there in question an ultra-short wave tube in which the ignition may be effected by means of three electrodes and preferably in braking field connection. The variable discharge chamber is bounded by the indirectly heated oxide cathode 80 and the grid 81, which is positively biased in relation to the cathode. Adjacent to the grid 81 is the igniting chamber of a chamber resonator, which igniting chamber is bounded by the braking electrode 82. All the three electrodes are made flat and arranged parallel to one another. Instead of the flat electrodes there may of course be provided electrodes that are slightly arched. The adjustment of the discharge path between the electrodes 80 and 81 is effected mechanically also in this case. The cathode is fastened on the cylindrical insulating body 83, which contains at its upper end also the heating body 84. This insulating body

83 is held by the annular metal body 85, which is made with a U-shaped cross-section and the external peripheral wall of which is provided with a screw-thread. Between a base plate 86 and the metal body 85 there is a metal corrugated tube 87, which is soldered or welded in a vacuum-tight manner to both parts. For adjusting there serves the screw nut 88 the upper end of which is guided on the plate 86. The base plate 86 is also welded or soldered in a vacuum-tight manner to the casing 89 of the cylindrical and disk-shaped resonator. Connected to the braking electrode 82 in the interior of the casing there is also a disk-like conductor 90, which forms essentially with the upper casing wall an energy conducting device of suitably chosen wave resistance for the coupling of the antenna 91 to the resonator. For this purpose the upper casing wall is provided with an opening 92 through which the antenna projects into the space of this energy conducting device, being conductively connected with the conductor 90. For the purpose of vacuum-tight closure, the opening is provided with a glass fusion joint 93, which serves also for the fastening of the antenna or the conductor 90 and the braking electrode 82. In order to enable the electrode 82 to be given a suitable potential, the peripheral wall of the casing 89 has an opening through which a lead 95 extends into the interior of the tube to the edge of the conductor 90. This opening is again provided with a vacuum-tight fusion joint 96.

The mode of operation of the arrangement is as follows: When the interior of the tube is brought to a high vacuum the conductor 85 carrying the cathode is under an external excess pressure, which presses the cathode in the direction of the grid until the upper edge of the conductor 85 bears on the base plate 86. In practice the construction will be so chosen that when the conductor 85 comes to bear the cathode 80 is applied exactly to the grid 81. If, now, the nut 88 is screwed over the thread of the conductor 85, the conductor 85 and consequently the cathode can be raised by the nut as soon as the end surface of the nut engages the base plate 86. If a thread of as fine a pitch as possible is selected, a very fine adjustment of the distance between the grid and the cathode may be effected thereby.

In order to enable oscillations to be produced and amplified with the tube with the highest possible efficiency, or the tube to be used as a highly selective receiver, the resonator has been given such a construction as to give it a particularly high wave resistance and consequently a specially small proper damping. Also the energy conducting device provided for the coupling of the antenna 90 is so constructed that there is a minimum of losses. The resonator and the energy-conducting device form together a system which consists essentially of three sections. The first section is formed by the chamber between the grid electrode 81 and the braking electrode 82, the wave resistance of which is made small in relation to the distance apart of the electrodes necessary for the production of small potentials. Adjoining this axially placed chamber there is a chamber of relatively great wave resistance which is bounded essentially by the resonator casing 89, the cylindrical part of the electrode 82, and the plate 90. The third chamber, the radial dimension of which is substantially greater than that of the igniting chamber between the electrodes 81 and 82, has again a relatively small wave resistance in order to receive

a small potential for the excitation of the antenna 91. If, now, an electronic stream of correct velocity passes through the grid and into the igniting chamber, the resonator is energized in such a manner that potential anti-nodes of the oscillations are formed between the electrodes 81 and 82 and at the place of entry of the antenna into the tube. As the radial dimension of the last part of the energy conducting device is substantially larger and the wave resistance substantially smaller than that of the igniting chamber, there occur at the foot of the antenna 91 smaller alternating potentials than between the electrodes 81 and 82. By the correct choice of these measurements in combination with the tuning of the antenna it is therefore possible to make an optimum coupling of the antenna and the resonator. The node surface of the alternating field is then located at any place between the casing 89 and the plate 90 so that there occur on both sides two node lines that are distinguished by the feature that between them there are no electric field lines and that the alternating current is there at a maximum. The lead 95 extends in this node surface, which is easily determined by calculation, and the escape of oscillation energy therethrough is thus completely prevented.

The bases for the calculation of the present resonator can in this case be found with the aid of the Bessel cylinder function. As compared with a simple disk-shaped resonator the present resonator has a very much greater wave resistance and therefore a very much smaller natural damping. As the radial dimension of the resonator is small in relation to the wave length, the upper casing wall is widened at the edge by the conductor 97 so that there is a sufficient counterbalance for the antenna 91.

The present tube construction is suitable not only for ignition in the braking field connection with a preferably negative braking electrode 82 but also for ignition with the help of other igniting mechanisms. Thus, for example, the electrode 82 may receive a high positive potential and the grid a negative potential, so that in the case of suitably chosen time of passage of the electrons between the grid and the anode or in the case of a suitably selected control potential between the cathode and the grid, an ignition of the resonator can result.

Figs. 9 and 10 show such a variable discharge chamber divided by a control grid in combination with a resonator formed as a chamber and working in reaction coupling connection. In this constructional example there are provided adjusting mechanisms by means of which the distances between the cathode and the grid and between the grid and the anode can be varied independently of one another. The adjusting mechanisms are quite similar to those of the preceding example.

In this case also there are a cathode 80 which is flat and is indirectly heated by means of the heating body 84, a flat grid 81, and an anode 82 that is likewise flat. The cylindrical cathode is connected with the disk-like body 98, which is supported by insulators 99 in relation to the upper casing wall 100 of the tube. The grid 81 occupies the middle portion of a metal plate 101 which is provided in the tube and which is supported so as to be insulated by insulators 102 in relation to the lower portion 103 of the tube casing. The two parts 100 and 103 of the casing are movable in relation to one another, the cylinder portion 104 of the upper part of the casing

forming a guiding device with the cylindrical portion 105 of the lower part of the casing. The two parts of the casing are connected together in a vacuum-tight manner by the elastic wall part 106 and are also provided with tubular parts 107 and 108 with threads of the same sense but of different pitches. The two parts of the casing are rigidly connected together by means of a nut 109 with corresponding counter-threads. As in the case of the preceding example, in this case also the two movable parts of the casing are pressed towards each other by the external excess pressure and can be moved apart by means of the nut in opposition to the external excess pressure. In this way the distance between the cathode 80 and the grid electrode 81 is adjustable and in particular is very accurately adjustable in the sphere of small distances apart of electrodes. By the employment of threads 107 and 108 of the same sense and with only slightly different pitches, an adjustment of any desired fineness can be effected. Now by means of a second and quite similar mechanism the distance between the grid 81 and the anode 82 can be varied. For this purpose the lower casing wall is provided with a thread part 110 and the cylindrical anode 82 guided in the casing wall 103 is provided with a thread part 111, these thread parts being engaged by a nut 112 in the same manner as in the case of the arrangement first described. Between the anode and the casing wall there is likewise an elastic metal intermediate wall 113 which is connected in a vacuum-tight manner with the two conductors. By adjusting the nut 112 any desired small distance apart between the grid and the anode can be exactly produced.

The upper casing wall contains, as in the case of the preceding example, an opening 92 through which the single antenna 114, 114' is led into the interior of the tube. The part 114' is adjustable in relation to the part 114 in order to enable the antenna to be tuned to the proper frequency of the resonator that is being ignited. The opening 92 is, as in the case of the preceding example, closed in a vacuum-tight manner by a glass fusion joint 93. The leads 115 pertaining to the cathode extend in a radial direction within and are insulated from the disk-shaped metal body 98 and extend through the tube casing at the edge of this disk. The opening through which the leads extend is likewise closed in a vacuum-tight manner by means of a glass fusion joint 93. The lead 116 for the grid electrode extends through the casing in a similar way and extends in an axial direction preferably within one of the insulators 102 to the plate 101.

The mode of operation of the tube is as follows: When the anode 82 receives a high positive potential and the grid 81 a positive or even negative potential in relation to the cathode, the tube can excite itself by reaction coupling. The chamber substantially determining the proper frequency of the resonator is the chamber between the grid electrode 81 and the anode 82 of relatively small wave resistance and the radially adjacent disk-like chamber of relatively great wave resistance. Now this chamber is excited as to its first harmonic oscillation in such a manner that potential anti-nodes of the oscillation are formed between the two electrodes and at the edge between the flat plate 101 and the casing and a node surface of the alternating potential is formed at an intermediate place, at which also are placed the insulators 102. Through the slit-like chamber between the edge of the plate 101 and the casing

of the tube the control resonator located above the plate 101 is coupled to the igniting resonator. By suitable choice of the distance between the plate 101 and the upper casing wall 100, or between the plate 101 and the disk-shaped metal body 98, it can be brought about that a potential anti-node is formed between the cathode and the grid and a node surface of the oscillations is formed at a certain radius, for example at the edge of the plate 98. A simple consideration shows that this control field between the cathode and the grid is opposite in phase to the field between the grid and the anode. Consequently when by suitable choice of the wave resistances or of the coupling of the control resonator to the igniting resonator, alternating amplitudes of sufficient magnitude are produced between the cathode and the grid, this control field is in the position to produce an alternating current which is substantially opposite in phase to the alternating potentials in the igniting chamber, so that the resonator is undamped, or can be caused to produce oscillations.

If the tube is to be worked with times of passage of the electrons that are comparable with the period of oscillation, for example equal to half the period of oscillation, means may be provided for the purpose of varying in relation to the alternating potential the phase of the alternating current entering the igniting chamber. Thus, for example, instead of a single grid 81 there may be provided two grids, the grid turned towards the cathode being the control grid proper and the one turned towards the anode being for example an attracting grid. By means of a suitable potential between these two grids there can be produced relatively to the alternating potential in the igniting chamber a leading or lagging of the current entering the igniting chamber.

The chamber between the upper part 100 of the casing and the metal plate 98 serves as an energy conducting device in exactly the same manner as in the case of the preceding example. It forms for the control resonator a partial short-circuit and serves for the purpose of producing an alternating potential between the two conductors in the axis by means of which a loose and optimum coupling of the antenna to the resonator is produced.

The calculation of the resonator may be made on the same basis as in the case of the resonator of the preceding example. It is to be observed in this case that the proper frequency of the resonator is also varied by the variation of the distance between the electrodes. In the case of very small distances between electrodes the proper frequency is smaller than in the case of great distances between electrodes. In the case of the present tube it is consequently possible to vary the proper frequency of the resonator within wide limits.

Fig. 11 shows finally a constructional example in which a two-electrode arrangement serves for igniting which can be advantageously used in the case of space charge control and in the case of favourably chosen time of passage of the electrons for the undamping or ignition of a resonator. In contradistinction to the preceding examples in which in the case of disk-like formation of the resonators the mutually adjustable electrodes were preferably made flat, there is here in question the employment of adjustable electrodes in the case of advantageously cylindrical formation of the resonator. As it is difficult in practice to vary the diameter of cylindrical electrodes, the

electrodes in this example are made frusto-conical.

The tube consists essentially of the cylindrical external conductor 115 and the internal conductor 116 co-axial therewith. Between the two a cylindrical metal body 117 is supported by means of insulators 118. The diameter of this metal body is much reduced in the middle portion and forms there the anode 119. The internal conductor is formed in the middle portion of the tube as an indirectly heated cathode 120 which can be heated by means of the heating body 121. The lower part 116' of the internal conductor that carries the cathode 120 is made adjustable axially and is guided by the lower end wall 122 of the casing. It projects a short distance out of the lower end of the tube and is provided with a flange 123, which has a thread, as has also the prolongation of the cylindrical conductor 115. Between the tube casing and the movable part 116' of the internal conductor there is provided again an elastic metal corrugated tube 124, which connects the two parts together in a vacuum-tight manner. By means of the nut 125, again, a micrometer adjustment can be effected. The upper end of the cathode 120 is provided with a guiding sleeve 126 in which fits accurately the upper part 116 of the internal conductor. The cathode and the anode are made slightly conical and in fact in such a manner that at all cross-sections there is between them the same distance. By adjusting the nut 125 the distance between the two anodes can accordingly be accurately adjusted between the value nil and a relatively great value. A specially fine adjustment is obtained when the peripheral edge of the cone is inclined only very little to the axis of the tube.

In order to enable a potential to be impressed upon the anode 119, the cylindrical body 117 is provided with a lead 127, which extends through the casing and is insulated in relation thereto. To the upper end of the internal conductor 116 is connected with the same cross-section the internal conductor 128 of an energy conducting device, and to this there is connected a $\lambda/4$ antenna 129. The external conductor of the energy conducting device is formed substantially by the cylindrical parts 130 and 131 and the flange-like parts connecting them. To the upper end of the conductor 131 is connected again a metal plate 132 serving as a counterbalance. The slit-shaped intermediate space at the edge of the energy conducting device is closed in a vacuum-tight manner by the glass fusion joint 93. For supporting the internal conductor 128 or 116 there serves the dielectric ring 137 which is advantageously arranged in a potential node of the field.

The resonator chamber proper is bounded by the internal conductor 116, 116', the cathode 120, and the cylindrical body 117, which is supported so as to be insulated. The space between the external conductor 115 and the body 117 forms a short-circuit condenser in the present case rendered dissonant in relation to the resonator. On the ignition of the resonator a potential anti-node is formed between the electrodes and potential nodes of the oscillation are formed at the two ends of the cylindrical space. The energy conducting device consisting of two sections of different wave resistances is connected to the resonator through the upper potential nodes and serves for the most favourable coupling of the antenna. The resonator and the energy conducting device have, as in the case of the preceding

examples, a formation which ensures a maximum wave resistance and consequently a small damping.

In consequence of the alteration of the distance between the electrodes there occurs in this case also, as in the case of the preceding example, a variation of the proper frequency of the resonator. If the resonator is to be used for a different wave-length the antenna 129 is advantageously made variable. By suitable tuning or untuning of the antenna there can be brought about within a relatively wide range the most favourable coupling to the resonator notwithstanding that the wave resistance of the energy conducting device is kept constant. The micrometer arrangement provided in the tube may likewise be graduated in distances apart or in wave lengths.

What I claim is:

1. An electron tube for working with ultra-high-frequency electromagnetic oscillations, comprising a resonator including electrodes, the resonator being surrounded by a vacuum vessel consisting of two parts connected together by a yielding wall, the proper frequency of the resonator being variable by a movement of said parts.

2. An electron tube for working with ultra-high-frequency electromagnetic oscillations, comprising a resonator including electrodes, the resonator being surrounded by a vacuum vessel having two parts connected together by a yielding wall, and a micrometer adjustment, said movable parts being connected with the micrometer adjustment.

3. An electron tube for working with ultra-high-frequency electromagnetic oscillations, comprising a resonator including electrodes surrounded by a vacuum vessel consisting of two parts connected together by a yielding wall, and a micrometer adjustment, the micrometer adjustment consisting essentially of a threaded member co-axial with the tube axis and with a

counter threaded member which engages in the second part symmetrically to the axis of the tube.

4. An electron tube for working with ultra-high-frequency electromagnetic oscillations, comprising a resonator including electrodes, the resonator being surrounded by a vacuum vessel consisting of two parts connected together by a yielding wall, and a micrometer adjustment, the force of the external air pressure that occurs between the tube sections being received by the micrometer adjustment connecting the two tube sections, and the adjustment of the tube in opposition to the air pressure being effected in the case of one direction of rotation of the movable micrometer part and the return by the air pressure itself being effected in the case of the other direction of rotation.

5. An electron tube for working with ultra-high-frequency electromagnetic oscillations, comprising a resonator including electrodes, the resonator being surrounded by a vacuum vessel consisting of two parts connected together by a yielding wall, and a micrometer adjustment which consist essentially of two threaded members co-axial with the axis of the tube and of slightly different pitches and each connected with a section of the tube, and a nut with corresponding counter threads to the threads of the threaded members for providing an adjustment proportional to the difference between the pitches of the threads of the threaded members.

6. An electron tube for working with ultra-high-frequency electromagnetic oscillations, comprising a resonator including electrodes, the resonator being surrounded by a vacuum vessel consisting of two parts connected together by a yielding wall, the resonator forming a chamber which is bounded by concentric and cylindrical conductors of predetermined lengths, a vessel-shaped external conductor, and a concentric internal conductor.

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