

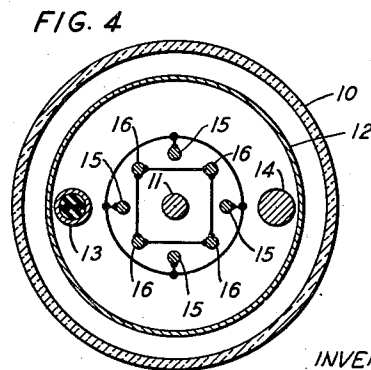
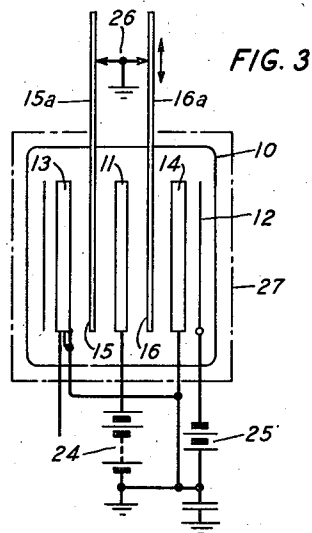
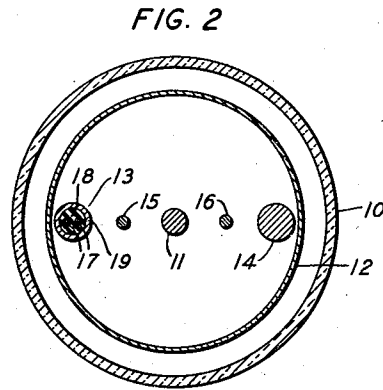
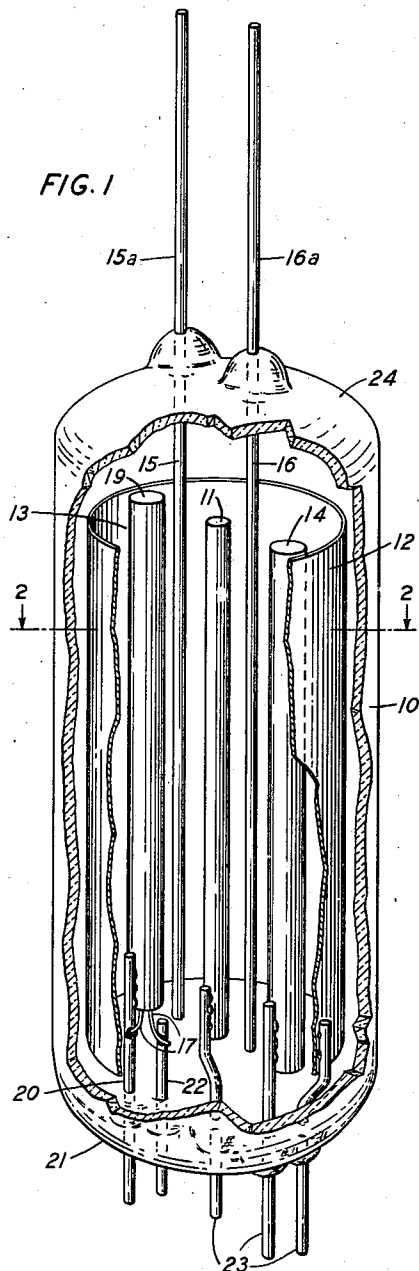
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ELECTRON DISCHARGE APPARATUS

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ELECTRON DISCHARGE APPARATUS

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This invention relates to electron discharge apparatus and more particularly to electronic oscillation generators operable at ultra-high frequencies.

As is known, in high frequency electronic oscillation generators, one of the principal factors determining the upper limit of the range of frequencies which can be generated is the electron transit time between the cathode and anode and even fairly efficient operation at ultra-high frequencies involves critical evaluation of the electron transit time. In general, if extremely high frequencies are to be generated, very close spacing of small electrodes and relatively high potentials between the electrodes are required. Such close spacing and high potentials introduce difficulties from the standpoint of insulation and, furthermore, the small sizes of the electrodes place definite limitations upon the power output which can be obtained.

In the Barkhausen-Kurz or braking field type of transit time oscillation generator, a large proportion of the electrons emanating from the cathode flow directly to the positive grid or anode and constitute what may be termed a conduction current thereto, whereas but a relatively small proportion of the electrons swing back and forth about the positive grid or anode in the form of a group oscillating space charge. Such oscillating space charge produces a high frequency current, which may be termed a displacement current, to the positive grid or anode, which is utilized in the output of the device. The conduction current does not contribute high frequency energy to the output of the device so that the efficiency inherently is relatively low and, furthermore, because of its heating effect limits the useful high frequency energy which may be obtained.

Moreover, Barkhausen-Kurz oscillators in general are operated with a cathode-temperature limited anode current which involves quite critical adjustment of the cathode heating current and may result in unstable operation.

One general object of this invention is to improve the operating characteristics of ultra-high frequency electronic oscillation generators.

More specifically, objects of this invention are:

To enable the generation of oscillations of extremely high frequencies, for example, frequencies corresponding to wave-lengths of the order of 25 centimeters or less;

To increase the high frequency energy obtainable from oscillation generators;

To increase the ratio of the displacement current to the conduction current in transit time oscillation generators whereby a high efficiency is achieved;

To increase the stability of operation of ultra-high frequency oscillation generators; and

To simplify and facilitate the construction of ultra-high frequency electronic oscillation generators.

In one illustrative embodiment of this invention, an oscillation generator comprises a cathode, preferably of the indirectly heated equipotential type, a positive electrode, and an auxiliary or braking field electrode, which may be cylindrical and encompass the cathode and the anode, the auxiliary electrode being operated at cathode potential or at a small positive or negative potential with respect to the cathode.

In accordance with one feature of this invention, the positive electrode is made comparable in size to the cathode and of relatively small area and is operated at such potential relative to the cathode that a region of dense space charge, i. e., a region of potential minimum, obtains in the immediate vicinity of the positive electrode.

In accordance with another feature of this invention, two or more output electrodes are mounted in proximity to the positive electrode. Preferably, one of the output electrodes is mounted between the cathode and the positive electrode and in alignment therewith, and another of the output electrodes is mounted on the opposite side of the positive electrode and in alignment therewith and with the cathode. This construction reduces the conduction current to the positive electrode and increases the displacement current whereby a high efficiency is obtained.

In accordance with still another feature of this invention the output electrodes are maintained at direct current ground potential and are connected to constitute in themselves a Lecher output system.

In accordance with a further feature of this invention, an auxiliary electrode, similar in form to the cathode and located with respect to the positive electrode similarly to the cathode, is provided to improve the electrical symmetry of the electrode structure and to provide balanced capacities to ground for the high frequency output electrodes.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is an enlarged perspective view of an electron discharge device illustrative of one embodiment of this invention, portions of the enclosing vessel and of the cylindrical auxiliary electrode being broken away to show the inner electrodes more clearly;

Fig. 2 is a view in section along plane 2—2 of Fig. 1 showing the configuration and relative disposition of the electrodes;

Fig. 3 is a circuit diagram illustrating operation of device shown in Figs. 1 and 2 as a high frequency oscillation generator; and

Fig. 4 is a cross-sectional view of a modification of the electron discharge device shown in Figs. 1 and 2.

Referring now to the drawing, the electron discharge device shown in Figs. 1 and 2 comprises an evacuated enclosing vessel housing a preferably central positive electrode or anode 11, a cylindrical auxiliary or braking field electrode 12 coaxial with the positive electrode or anode 11, a cathode 13, an auxiliary electrode 14, and a pair of similar output electrodes 15 and 16. As shown clearly in Fig. 2, the cathode and positive, auxiliary and output electrodes are mounted parallel to one another and in alignment, the positive electrode 11 is of somewhat smaller cross-section than the cathode 13 and the auxiliary electrode 14 is of substantially the same size and cross-section as the cathode 13.

The cathode, as shown, preferably is of the indirectly heated equipotential type and comprises a heater filament 17 encased in an insulating material 18 which is encompassed by a cylindrical metallic sleeve 19 the outer surface of which is coated with a thermionic material, such as barium and strontium oxides. The cathode may be supported by a rigid leading-in conductor 20 affixed to the sleeve 19 and sealed in the end wall 21 of the vessel 10. Heating current for the filament 17 may be supplied through the leading-in conductor 20 and another leading-in conductor 22 also sealed in the end wall 21.

The auxiliary electrodes 12 and 14 may be supported by rigid leading-in conductors 23 sealed in the end wall 21 of the enclosing vessel 10.

The output electrodes 15 and 16, which are equally spaced on opposite sides of the positive electrode 11, are sealed in the end wall 24 of the enclosing vessel 10 and are provided with relatively long, integral extensions 15a and 16a respectively, the purpose of which will be described hereinafter.

Although the invention is not limited thereto, the following dimensions are illustrative of those which may be employed. The positive electrode 11 may have a diameter of 0.030 inch, the auxiliary hollow cylindrical electrode 12 may have an inside diameter of 0.500 inch, and the cathode 13 may have an outside diameter of 0.065 inch and be spaced 0.205 inch, center to center, from the positive electrode 11. The auxiliary electrode 14, as noted heretofore, may be of the same size as the cathode 13 and be spaced from the positive electrode 11 the same distance as the cathode 13. The output electrodes 15 and 16 may be 0.015 inch in diameter and spaced 0.100 inch, center to center, from the positive electrode 11.

During operation of the device, as illustrated in Fig. 3, the auxiliary electrode 14 is connected directly to the cathode 13 and the anode or positive electrode 11 is maintained at a posi-

tive potential, for example of the order of 500 volts, with respect to the cathode 13 by a source such as a battery 24. The auxiliary electrode 12 may be maintained at a small positive or negative potential with respect to the cathode 13 by a source such as a battery 25. Alternatively, the auxiliary electrode 12 may be connected directly to the cathode 13 and operated at cathode potential. The extensions 15a and 16a of the output electrodes are bridged by a slide member 26 connected to ground so that the output electrodes, which constitute a tunable Lecher system, are operated at direct current ground potential.

When the cathode 13 is energized and potential differences are established between the electrodes as described above, electrons from the cathode 13 will flow toward the positive electrode 11 and, inasmuch as the surface of the electrode 11 is comparable with that of the cathode, a region of dense space charge is established in the immediate vicinity of the electrode 11. Some of the electrons will miss the electrode 11 on their initial movement, be retarded by the field of the electrodes 12 and 14, and spiral or oscillate about the electrode 11 before being collected thereby, these electrons augmenting the dense space charge region. Because of the alignment of the output electrodes 15 and 16 with one another and the electrode 11, they serve as barriers reducing the number of electrons which flow directly to the positive electrode 11 and increase the number of electrons oscillating or spiraling about the electrode 11. Hence, a high ratio of displacement current to conduction current obtains.

The electrons spiraling or oscillating about the electrode 11 will first give a charge to one output electrode, 15 for example, and then to the other output electrode, and this phenomenon is repeated. Hence, an oscillating current will be produced in the Lecher system including the output electrodes 15 and 16 and their extensions 15a and 16a. The frequency of this current will be determined by the length of the electronic path between the output electrodes and upon the potential of the positive electrode 11. Inasmuch as the electrodes 15 and 16 may be closely spaced, the electron transit time therebetween will be but a fraction of the electron transit time between the cathode 13 and the positive electrode 11. Hence, the frequency of the oscillations generated will be several times as great as that which could be obtained as limited by the cathode to anode electron transit time. The oscillating circuit should be tuned, of course, to the transit time frequency for maximum efficiency.

The auxiliary electrode 14, it will be apparent, assures electrical symmetry of the electrode structure and, furthermore, enables balanced capacities to ground for the output electrodes 15 and 16. Because of this, the positive electrode 11 absorbs practically no high frequency energy so that the conduction current and displacement currents are substantially segregated. Hence, precautions from the standpoints of dielectric losses, sealing in the vessel 10, and impedances, need be observed only in bringing out the extensions from the output electrodes and no special precautions are necessary in bringing out the leading-in conductors for the other electrodes.

In a specific device wherein the electrodes were of the dimensions and spacings noted above, oscillations of 25 centimeter wave-length were produced with 500 volts on the positive electrode 11 and a current of but 2 milliamperes to this elec-

trode, the oscillating frequency being about four times that which could be expected from the calculated cathode to positive electrode electron transit time. With smaller electrodes and closer electrode spacings, oscillations of even shorter wave-lengths can be obtained. Such reductions in dimensions are quite practical inasmuch as the heating effect of the current to the positive electrode 11 would not be prohibitive.

Preferably, as shown in Fig. 3, the device 10 is enclosed in a metal radiation shield 27 to increase the output energy.

The wave-length of the oscillations obtainable may be reduced by employing a greater number of output electrode elements. For example, as shown in Fig. 4, each output electrode may comprise a plurality of equally spaced parallel elements electrically connected together, the elements of the two electrodes being alternately arranged and equally spaced from and parallel to the positive electrode 12. The oscillating frequency, then, will be determined by the electron transit time between successive elements of the output electrodes, that is, between each element of the electrode 15 and the next adjacent element of the electrode 16.

The multielement electrodes 15 and 16 in Fig. 4 may constitute arms of a tunable Lecher system including a bridge 26 as in Fig. 3.

It may be pointed out that use is made of an indirectly heated equipotential cathode, from which the current to the positive electrode 11 is limited by space charge and not by cathode temperature as in conventional devices, so that stable operation is achieved.

Although specific embodiments of this invention have been illustrated and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a cathode, a linear anode spaced from said cathode, means including said cathode for producing a spiraling cloud of electrons about said anode, and an output circuit including a pair of substantially identical spaced electrodes at direct current cathode potential in proximity to and equally spaced from said anode and a tuned circuit connected between said last-mentioned spaced electrodes.

2. Electron discharge apparatus in accordance with claim 1 wherein said cathode and anode are parallel, cylindrical and of comparable areas and one of said spaced electrodes is a linear member mounted between said cathode and anode and in alignment therewith.

3. An oscillation generator comprising a cathode, an anode spaced from said cathode and of an area commensurate with the area of said cathode, a braking field electrode encompassing said cathode and said anode, means maintaining said anode at a high positive potential with respect to said cathode, means applying a braking potential to said braking field electrode, and an output circuit comprising a pair of substantially identical spaced electrodes in proximity to and equally spaced from said anode and a tuned circuit connected between said last-mentioned spaced electrodes.

4. An oscillation generator in accordance with

claim 3 wherein one of said spaced electrodes is mounted between said cathode and said anode and in alignment therewith.

5. An oscillation generator comprising a cathode, an anode spaced from said cathode and of an area commensurate with the area of said cathode, a braking field electrode encompassing said cathode and said anode, means maintaining said anode at a high positive potential with respect to said cathode, means applying a braking field potential to said braking field electrode, an output circuit comprising a pair of spaced electrodes in proximity to said anode, and an auxiliary electrode of the same form as said cathode and connected thereto, said cathode and said auxiliary electrode being mounted in alignment on opposite sides of said cathode and equally spaced therefrom.

6. An oscillation generator comprising a cathode electrode and an auxiliary electrode of the same form and dimensions as said cathode mounted in spaced relation and electrically connected together, an anode electrode mounted substantially midway between said cathode and said auxiliary electrode, a pair of linear output electrodes in proximity to said anode, an additional electrode surrounding said electrodes, and means for connecting said surrounding electrode to said cathode.

7. An oscillation generator in accordance with claim 6 wherein said output electrodes are mounted on opposite sides of said anode and in alignment with said cathode and said anode.

8. An oscillation generator comprising a cathode, an anode of an area commensurate with that of said cathode, means including said cathode for producing a spiraling cloud of electrons about said anode, and an output circuit consisting of a pair of parallel linear members at direct current cathode potential having electrode portions in proximity to and spaced electrically symmetrical with respect to said anode and a bridging member engaging said members.

9. An oscillation generator comprising a linear cathode, a linear rod anode of an area commensurate with that of said cathode mounted parallel to said cathode, a cylindrical braking field electrode encompassing said anode and said cathode and coaxial with said anode, means maintaining said anode at a high positive potential and said field electrode at a low potential with respect to said cathode, and a pair of linear output electrodes at direct current cathode potential in proximity to said anode and parallel thereto, and an auxiliary electrode substantially identical in form to said cathode and electrically connected thereto, said cathode and auxiliary electrode being mounted symmetrically on opposite sides of said anode.

10. An oscillation generator comprising a cathode, an anode commensurate in area with said cathode and spaced therefrom, means including said cathode for producing a spiraling cloud of electrons about said anode, a pair of output electrodes each including a plurality of electrically integral linear members equally spaced about said anode, the linear members of each output electrode being mounted in alternate relation with the linear members of the other output electrode, and a tuned circuit connected between said output electrodes.

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