

Sept. 2, 1941.

E. BRUCE

2,254,265

ELECTRON DISCHARGE APPARATUS

Filed Oct. 6, 1939

2 Sheets-Sheet 1

FIG. 1

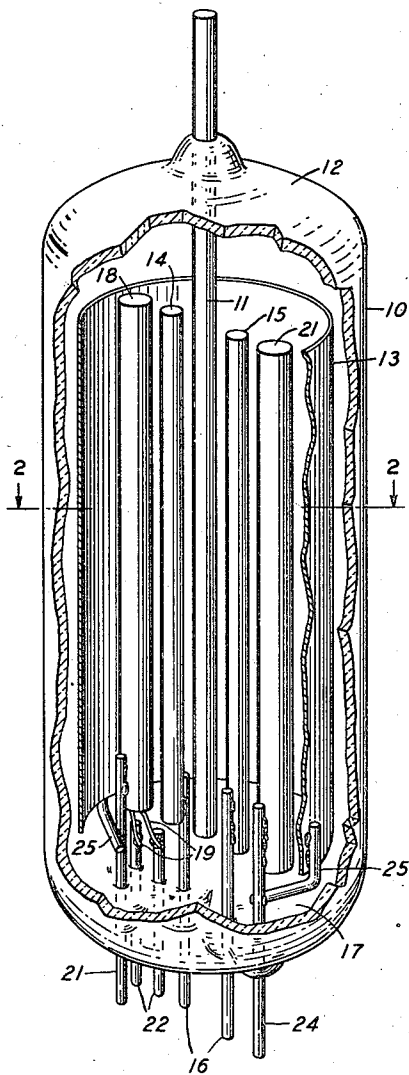


FIG. 2

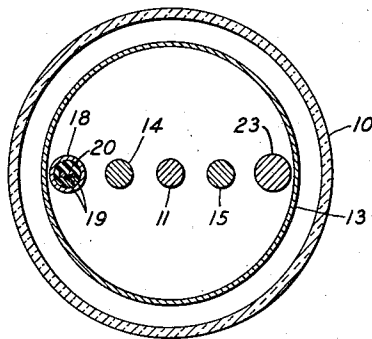
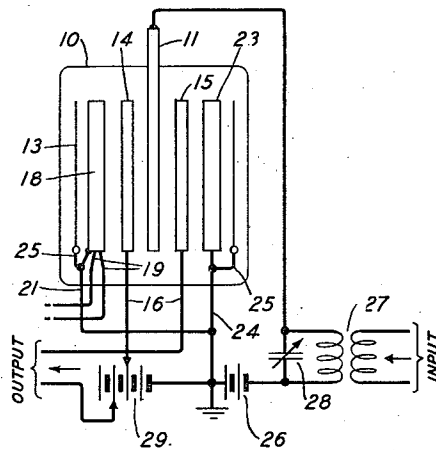


FIG. 3



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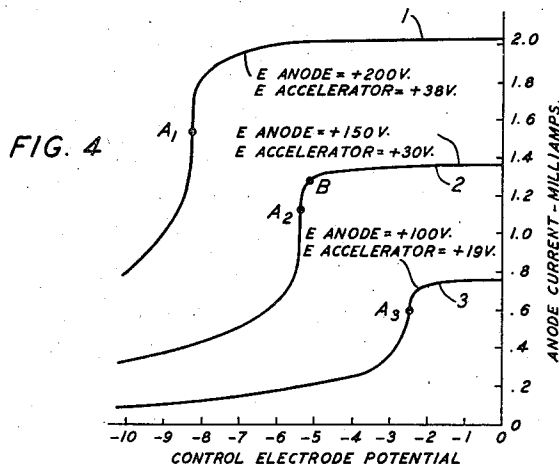


FIG. 5

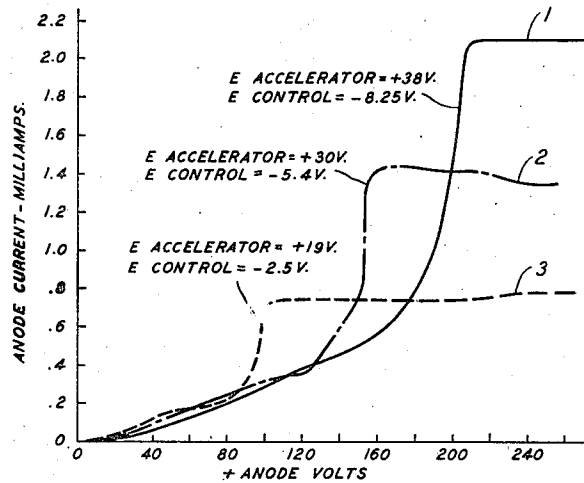
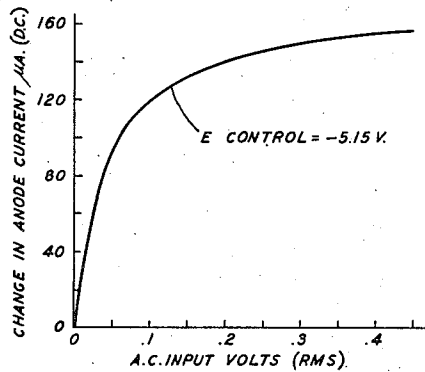


FIG. 6



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ELECTRON DISCHARGE APPARATUS

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Application October 6, 1939, Serial No. 298,204

9 Claims. (Cl. 250—27)

This invention relates to electron discharge apparatus and more particularly to such apparatus of the general type disclosed in my application Serial No. 134,008, filed March 31, 1937, now Patent 2,193,578, granted March 12, 1940. More specifically, this invention relates to electron discharge devices operable as detectors and amplifiers at high frequency.

One object of this invention is to increase the operating range of electronic detectors and amplifiers. More specifically, one object of this invention is to enable detection and amplification of impulses of extremely high frequencies, for example, frequencies corresponding to wavelengths of the order of 10 centimeters.

Another object of this invention is to obtain a high transconductance for ultra-high frequency electronic amplifiers.

A further object of this invention is to increase the sensitivity of ultra-high frequency electronic detectors.

Still another object of this invention is to prevent transit time parasitic oscillations in electronic amplifiers and detectors.

In one illustrative embodiment of this invention, an electron discharge device comprises generally a cathode, an anode and a control electrode mounted in spaced relation within a cylindrical shield electrically connected to the cathode or maintained at a low potential, the cathode, anode and control electrode being spaced in relatively close proximity to enable the attainment of short electron transit times.

In accordance with one feature of this invention, the cathode, anode and control electrode are linear, parallel elements, the control electrode being mounted between the cathode and the anode and the longitudinal sectional area of the anode being comparable with, and preferably smaller than, that of the cathode.

In accordance with another feature of this invention, the anode is located unsymmetrically with respect to the cylindrical shield electrode whereby transit time parasitic oscillations are prevented.

In accordance with a further feature of this invention, a linear auxiliary electrode is provided between the cathode and the control electrode and in alignment therewith and is maintained at a positive potential whereby a field promoting flow of electrons from the cathode is produced and a region of dense space charge in the vicinity of the anode is established.

In accordance with still another feature of this invention, the auxiliary electrode and anode are

maintained at such potentials that a substantially linear sharply increasing relation obtains, for a restricted range of control electrode potentials, between the control electrode potential and the anode current.

In accordance with a still further feature of this invention, the potentials on the several electrodes are made such that the electron transit time is tuned to the frequency to be detected or amplified.

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 drawings in which:

Fig. 1 is an enlarged view in perspective of an electron discharge device constructed in accordance with this invention, portions of the enclosing vessel and of the shield electrode being broken away to show the inner electrodes and details of construction more clearly;

Fig. 2 is a view in section along plane 2—2 of Fig. 1;

Fig. 3 is a circuit diagram showing one way of operating the electron discharge device illustrated in Figs. 1 and 2;

Fig. 4 is a graph illustrating the relation between control electrode voltage and anode current in apparatus constructed in accordance with this invention;

Fig. 5 is another graph illustrating the relation between anode current and anode voltage in apparatus constructed in accordance with this invention; and

Fig. 6 is still another graph illustrating the sensitivity of electronic detectors constructed in accordance with this invention.

Referring now to the drawings, the electron discharge device shown in Figs. 1 and 2 comprises an evacuated enclosing vessel 10 housing a linear control electrode 11, which may be sealed in one end wall 12 of the vessel 10 as shown, and a cylindrical shield electrode 13 encompassing and coaxial with the control electrode 11. Mounted on opposite sides of the control electrode 11, parallel thereto and in alignment with one another are a linear auxiliary electrode 14 and a similar anode 15, which may be supported by rigid leading-in conductors 16 sealed in the other end wall 17 of the enclosing vessel 10. Alternatively, the electrode 14 and anode 15 may themselves be sealed in the end wall 17. As shown in Fig. 2, the anode 15 and auxiliary and control electrodes 14 and 11 respectively may be of substantially equal cross-sectional areas

and the electrodes 14 and 15 may be equally spaced from the electrode 11.

Mounted between the auxiliary electrode 14 and shield 13 is a linear cathode, which may be of the equipotential indirectly heated type and comprises a metallic sleeve 18 coated on its outer surface with a thermionic material, and a heater filament 19 enclosed in a ceramic insulating material 20. As shown in Fig. 2, the cathode 18 is parallel to and in alignment with the auxiliary and control electrodes 14 and 11 respectively. Preferably, the cathode is of a cross-sectional area somewhat greater than that of the anode 15. The cathode may be supported by a rigid leading-in conductor 21 sealed in the base wall 17, and current may be supplied to the heater filament 19 through leading-in conductors 22 also sealed in the base wall 17.

It will be understood, of course, that other types of cathodes, for example, filamentary, may be employed. Whatever type of cathode is employed, the cathode dimensions should be commensurate with and preferably somewhat larger than those of the anode.

Mounted on the side of the anode 15 remote from the control electrode 11 is an auxiliary electrode 23, preferably substantially identical in form with the cathode 18 and parallel to the anode 15, supported by a rigid conductor 24 sealed in the wall 17. As shown in Fig. 2, preferably the cathode 18 and auxiliary electrode 23 are equally spaced from the control electrode 11. As indicated in Fig. 1, the auxiliary electrode 23 and shield 13 may be connected directly to the cathode 18 through rigid tie wires 25, which, it will be noted, support the shield 13 from the leading-in conductors 21 and 24. Alternatively, the shield 13 may be electrically separate from the cathode and have a small negative potential applied thereto.

Although the invention is not limited thereto, the following dimensions are practical for a device operable at frequencies corresponding to wave-lengths of the order of 10 centimeters. The control electrode 11 may be 0.030" in diameter and coaxially disposed in a shield 13 having an internal diameter of 0.500". The accelerating electrode 14 and anode 15 may be 0.030" in diameter and spaced 0.100", center to center, from the control electrode 11. The cathode 18 and auxiliary electrode 23 may be 0.065" in diameter and spaced 0.205", center to center, from the control electrode 11.

During operation of the device, as illustrated in Fig. 3, the control electrode 11 is biased negatively with respect to the cathode 18 by a source such as a battery 26 and the signals to be detected or amplified are impressed between the cathode and control electrode through the secondary winding of an input transformer 27. The input circuit may be tuned to the operating frequency by a tunable system illustrated by the variable condenser 28 connected across the secondary winding of the transformer 17. For ultra-high frequency operation, the tunable system may be a Lecher system or a pair of coupled Lecher frames.

The anode 15 is maintained at a positive potential with respect to the cathode 18 by a source, such as a battery 29, the output circuit being as shown. The accelerating electrode 14 may be connected to an intermediate point on the battery 29 and maintained at a positive potential with respect to the cathode 18.

When the device is operated, electrons emanat-

ing from the cathode 18 will be accelerated toward the anode 15 by the accelerating electrode 14. Because of the potential of the electrode 14, flow of electrons from the cathode region will be enhanced and the production of a field unfavorable to the flow of electron current by the shield 13 and negatively biased control electrode 11 will be prevented. This, together with the fact that the anode 15 is commensurate in area with the cathode 18 assures a concentration of the electrons in the immediate vicinity of the anode whereby a dense space charge region and potential minimum in proximity to the control electrode 11 and anode is established. This dense space charge region is augmented by electrons which miss the anode in their original flight and come under the influence of the retarding field of the auxiliary electrode 23 and shield 13. Such electrons revolve or spiral about the anode 15 before being collected by it. The control electrode 11, therefore, can exercise effective control upon this region so that a very high transconductance is obtainable. The effective electron transit time is a function of the distance between the dense space charge region and the anode and, inasmuch as this distance is very small as compared with the cathode to anode spacing, the effective transit time is very small as compared with the cathode to anode transit time. Hence, operation at extremely short wave-lengths is enabled inasmuch, as is known, the frequency limit of operation of an electron discharge device is directly and largely dependent upon the electron transit time.

The electron transit time is dependent, of course, upon the potential of the anode. For maximum efficiency and in order to assure stable operation at extremely high frequencies, it has been found that the transit time should be tuned to the frequency at which the device is to be operated. This may be accomplished in the arrangement shown in Fig. 3 by carefully adjusting the potential applied to the anode so that for an input of any particular frequency and with the system 27, 28 tuned to this frequency the output is a maximum.

As will be clear, particularly from Fig. 2, the accelerating electrode 14 serves as a barrier between the cathode 18 and anode 15 so that conduction current to the anode is reduced. Furthermore, inasmuch as the electrodes may be made of small areas, very small interelectrode capacitance obtain. For example, in a device of the construction described hereinabove, an anode to control electrode capacitance as low as 0.4 micro-microfarad with an anode to all other electrodes capacitance of 0.9 micro-microfarad and a control electrode to all other electrodes capacitance of 0.7 micro-microfarad have been obtained. Moreover, it will be noted that because of the non-symmetry of the electrode system with respect to the anode, the conduction and high frequency currents are substantially segregated and electrons are always approaching the control electrode whereby the generation of parasitic oscillations is prevented.

Typical operating characteristics for electron discharge apparatus constructed in accordance with this invention are illustrated in Figs. 4 and 5. In Fig. 4, anode currents are plotted as ordinates against abscissae of control electrode potential and, therefore, the elementary slope at any point in the curves represents the control electrode-anode transconductance. It will be noted that each of the three curves shown in

Fig. 4 includes an almost vertical linear portion. For control electrode potentials corresponding to these portions very high transconductances obtain. Hence, if the control electrode is biased at the point A₁, A₂ or A₃, depending upon the anode potential (E anode) indicated in Fig. 4, very high amplification may be obtained. As will be noted from Fig. 4, the extent of the linear vertical portion is dependent upon the anode potential, increasing in extent with increasing anode potential.

Fig. 5 indicates the anode current-anode potential characteristic in devices wherein the control electrode is biased at the point A₁, A₂ or A₃, corresponding curves in Figs. 4 and 5 being designated by the same reference numeral, i. e., 1, 2 or 3. In Fig. 5, elemental slopes of the curves, of course, represent the anode resistance. It will be apparent from this figure, that marked changes in anode resistance are obtainable with small changes in anode potential.

It will be noted from Figs. 4 and 5 that extremely sensitive detection can be realized. For example, if the control electrode is biased at the point B on curve 2 in Fig. 4, the anode current will vary with an alternate current signal impressed between the cathode and control electrode as indicated by the curve in Fig. 6. As will be apparent from Fig. 6, a change of 0.1 volt in the control electrode potential results in a relatively great change, about 120 microamperes, in the average anode current.

Although a specific embodiment of the invention has been shown and described, it will be understood, of course, that it is 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, an accelerating electrode and an anode mounted in alignment and parallel to one another, said accelerating electrode being between said cathode and said anode and said cathode and said anode comprising linear members of commensurate areas, a control electrode in proximity to said anode, means applying positive potentials to said accelerating electrode and anode with respect to said cathode, and means including an auxiliary electrode having a portion on the side of said anode remote from said cathode for producing a low potential field on said side, said cathode and anode being unsymmetrically mounted with respect to said auxiliary electrode, and said positive potentials and low potential field being such that a region of minimum potential obtains in the immediate vicinity of said anode.

2. Electron discharge apparatus in accordance with claim 1, wherein said auxiliary electrode comprises a cylinder encompassing said cathode and anode and eccentric with said cathode and anode.

3. Electron discharge apparatus comprising a linear cathode and a slender linear anode in cooperative relation therewith, said anode and cathode being of commensurate areas, means for producing a field having a region of potential minimum in the immediate vicinity of said anode, said means including a source applying a positive potential of such magnitude to said

anode that the electron transit time between said region and said anode is substantially tuned to the period of the frequency at which said apparatus is to be operated, and an input circuit including a control electrode adjacent said anode.

4. Electron discharge apparatus comprising a cylindrical shield electrode, a linear control electrode coaxial with said shield electrode and encompassed thereby, a cathode and a linear rod anode on opposite sides of said control electrode and within said shield electrode, and an accelerating electrode between said cathode and said control electrode.

5. Electron discharge apparatus comprising a linear cathode, an anode consisting of a linear rod of an area commensurate with that of said cathode mounted parallel to said cathode, a linear wire control electrode between said cathode and said anode and in alignment therewith, a linear wire accelerating electrode between said cathode and said control electrode and parallel thereto, and a cylindrical shield electrode encompassing said cathode, anode and control and accelerating electrodes.

6. Electron discharge apparatus in accordance with claim 5 comprising an auxiliary electrode opposite the side of said anode remote from said cathode and in alignment with said anode and said cathode.

7. Electron discharge apparatus comprising a cylindrical shield electrode, a linear rod anode within said shield electrode and eccentric with respect thereto, a cathode within said shield electrode and parallel to said anode, said cathode and anode being of comparable areas, and a linear wire control electrode within said shield electrode, concentric therewith and mounted in proximity to said anode and relatively remote from said cathode.

8. Electron discharge apparatus comprising a linear control electrode, a cylindrical shield electrode encompassing said control electrode and substantially coaxial therewith, a linear wire accelerating electrode and a linear wire anode on opposite sides of said control electrode and in alignment therewith and with one another, a cathode opposite the side of said accelerating electrode remote from said anode and in alignment with said anode and accelerating electrode, and an auxiliary electrode substantially identical in form to said cathode mounted opposite the side of said anode remote from said control electrode, and in alignment with said control electrode and anode, said auxiliary and control electrodes being substantially equally spaced from said control electrode, and said shield electrode encompassing said cathode and auxiliary electrode.

9. An ultra-short wave detector comprising a cathode and an anode in spaced relation, an output circuit connected between said cathode and said anode including a source for applying a positive potential to said anode, a tunable input circuit including a control electrode in proximity to said anode, and means including said source for producing a dense space charge region in the immediate vicinity of said anode, said input circuit being tuned to the frequency to be detected, and said potential being such that the electron transit time between said region and said anode is tuned to the period of said frequency.

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