

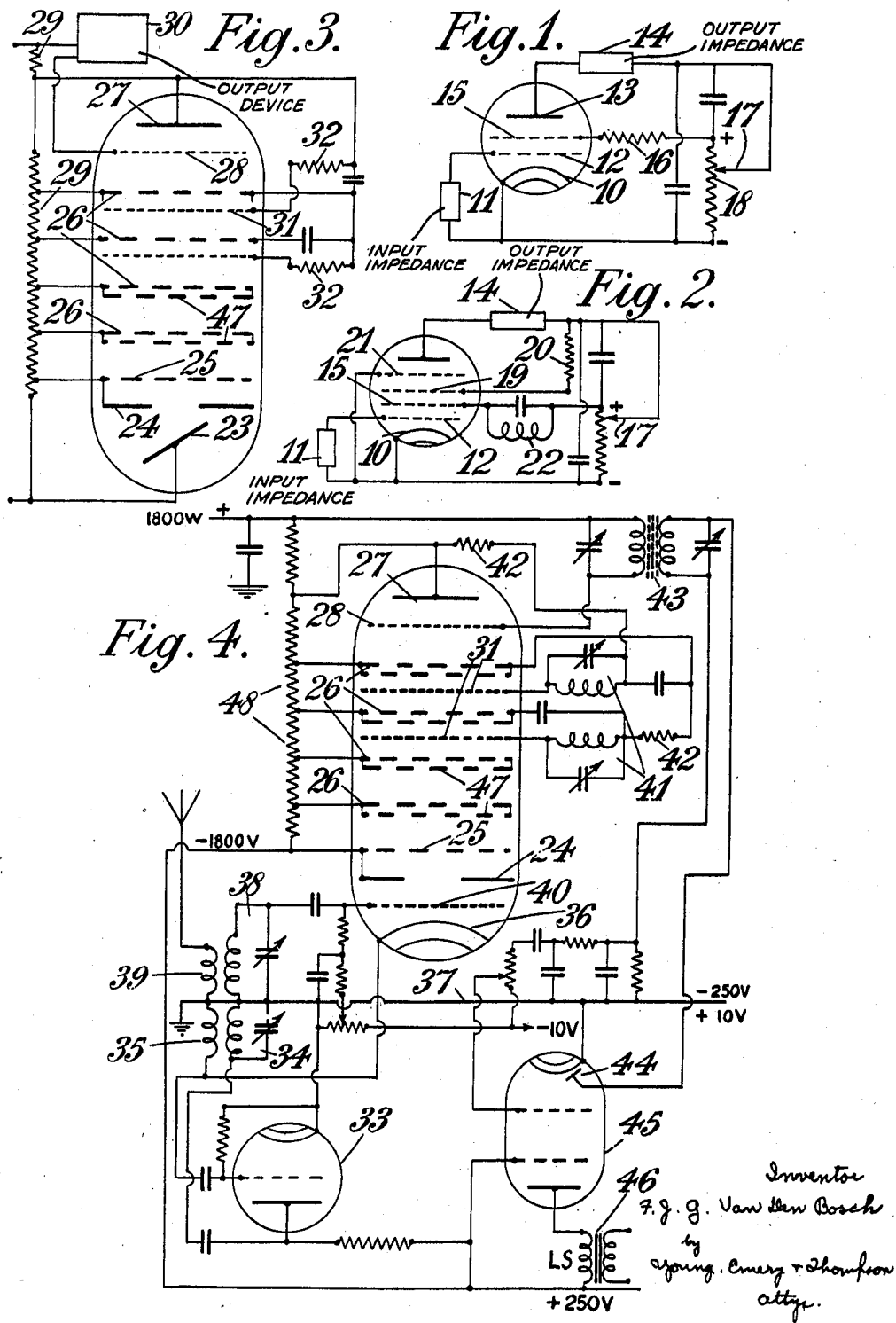
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ELECTRON DISCHARGE APPARATUS

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ELECTRON DISCHARGE APPARATUS

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This invention relates to electron discharge apparatus and is concerned with such apparatus comprising an electron discharge device having a cathode and an anode operated at a positive potential with respect to the cathode and with or without intermediate electrodes affecting the electron stream between the cathode and the anode. In use of such apparatus signal or like variations of the space current are produced by varying the cathode emission by applying varying control potentials of one or more intermediate electrodes, or by varying the positive potential applied to the anode. Difficulties or limitations in the operation of such apparatus arise on account of the standing or D. C. component of the space current at the anode becoming impracticably large. For instance, difficulties may arise because of thermal agitation at the anode or in regard to the heat dissipation at the anode.

According to the present invention there is provided an electron discharge apparatus of the kind referred to comprising an electron discharge device which has a by-passing or controlling electrode in the electron path between the cathode and the anode connected by a resistance and/or impedance to means for applying to this electrode a positive potential above zero which, under conditions of no space current, is of the same polarity with respect to the cathode but greater than that applied to the next succeeding accelerating or collecting electrode, the value of which resistance is so selected that the space current flowing by way of the by-passing electrode produces a potential drop across the resistance such that the by-passing electrode assumes a potential of the same order as that applied to the next following electrode. Under normal working conditions there is a space current flowing between the anode and the cathode, but owing to the comparatively high potential applied to the said controlling electrode a proportion of the space current is diverted by way of this controlling electrode and its associated resistance and/or impedance so that the current flowing by way of the anode is correspondingly decreased. By diverting a proportion of the space current in this manner, the cathode emission may be increased so that, with a given grid control, the slope of the grid volts-anode or collector current characteristic may be increased without increasing the dissipation at the anode or collector. Preferably, the space current flowing by way of the controlling electrode produces a potential drop across resistance in current therewith such that the controlling electrode as-

sumes a potential of the same order as that applied to the next following accelerating or collecting electrode.

According to a further feature of the invention the impedance in circuit with the controlling electrode comprises frequency selective means for extracting a selected signal frequency from or injecting a selected frequency or frequencies into the space current. Thus, for extracting selected signal frequencies, such frequency selective means has therefore a higher impedance for such frequencies than other frequencies and consequently signal variations for which the selective means provides low impedance will be by-passed from the anode or output of the electron discharge device and so render the apparatus selective for other frequencies.

One application of the invention is an electron discharge apparatus employing an electron discharge device having one or more secondary cathodes and according to a further feature of this invention a controlling electrode, as aforesaid, is provided adjacent to a secondary cathode. The magnification obtainable with an electron multiplier is normally restricted due to the standing current through the multiplier. The standing current is determined by the cathode and any electrodes acting with primary emission from the cathode and owing to electron multiplication becomes a maximum in the final stage of the multiplier. Whereas an increase in the primary electron space current would enable an increase in overall magnification to be obtained corresponding increase in the standing current of the final stage of the multiplier may become impracticably large. This disadvantage is overcome by means of the present invention in which a portion of the standing current is by-passed by way of the aforesaid controlling electrode.

The invention also comprises an electron discharge apparatus employing an electron discharge device having a plurality of secondary cathodes for successive stages of electron multiplication, wherein a controlling electrode as aforesaid is positioned in front of a secondary cathode and is connected through said resistance and/or impedance to the next following secondary cathode.

Specific embodiments of the invention are shown by way of example in the accompanying drawing, in which—

Figures 1 and 2 are diagrams of thermionic valve apparatus embodying the invention;

Figure 3 is a diagram of an electron multi-

plier apparatus with resistance loading of a by-passing or controlling electrode, and

Figure 4 is a diagram of another electron multiplier apparatus employing selective means in conjunction with a controlling electrode.

Referring to Figure 1 of the drawing, there is shown a thermionic valve amplifier comprising a cathode 10, an input impedance 11 connected between the cathode and an input grid 12 and an anode 13 with an output impedance 14 connected in circuit therewith. According to this invention a by-passing or controlling grid 15 provided between the input grid 12 and the anode 13 is connected through a load resistance 16 to the positive pole of a high tension supply, the negative pole being connected to the cathode of the valve. The high tension supply to the anode is taken from a tapping 17 on a potential divider 18 connected across the high tension supply so that under conditions of no space current the controlling grid 15 has a higher potential than the anode 13. With the normal space current a part of this current is diverted from the anode by the controlling electrode 15 and a potential drop is produced across the loading resistance 16. The value of the loading resistance 16 preferably has such a relationship with the cathode emission and any control by the input electrode 12, that the electrode 15 assumes a potential of the same order as that applied to the anode 13. With this arrangement a proportion of the standing current is diverted from the anode and thus enables an increased total space current to be used.

In Figure 2 there is shown the application of the invention to another form of thermionic valve amplifier in which there is employed, in addition to the input grid 12, a space charge grid 19 connected through a resistance 20 to the tapping point 17 for the anode high tension supply and a screening grid 21 connected to the cathode 10. The controlling electrode 15 for the purpose of the present invention is positioned between the input grid 12 and the space charge grid 19 and is connected in this case through a parallel tuned circuit 22 to the positive pole of a high tension supply. The tuned circuit 22 offers a high impedance to a wanted band of frequencies and considerably less impedance to other frequencies, so that signal variations within the wanted band of frequencies applied to the valve by the input impedance 11 are impeded by the tuned circuit 22, whereas for signal variations at other frequencies a proportion of the space current is by-passed by way of the tuned circuit and these signal variations are suppressed at the anode of the valve. In this case also a loading resistance may be connected in series with the tuned circuit 22 or may be incorporated in the tuned circuit itself so as to reduce the standing current flowing by way of the anode as described with reference to Figure 1.

An application of the invention to a photo electron multiplier apparatus is shown in Figure 3 in which there is employed a photoelectric cathode 23, the electron emission from which is directed by means of an accelerator 24 on to a secondary cathode 25. This secondary cathode is followed by other secondary cathodes 26, a final secondary cathode 27 and a collector 28 in the form of a grid, perforated plate or the like. Each of the secondary cathodes 25 and 26 are in the form of a wire grid or mesh or perforated plate, or are of any other construction providing a surface on which the approaching electrons may

impinge and apertures through which the secondary electrons may pass to a succeeding electrode. For example, these secondary cathodes are of the form described in specification of my United States Patent No. 2,254,128. In front of each of the first two of the secondary cathodes 26 there is an auxiliary electrode 47 connected to the associated secondary cathode so as to be operated at the same potential, as described in specification of my United States patent application Serial No. 326,813, filed March 29, 1940.

Operating potentials positive with respect to the photoelectric cathode 23 are derived from a potential divider 29 for connection across a high tension supply. The secondary cathodes 25, 26 and 27 and the collector 28 are connected to tapping points on this potential divider so as to have progressively increasing positive potentials with respect to the photoelectric cathode 23. The lead to the collector 28 includes an output device indicated at 30.

In front of each of the last two secondary cathodes 26 there is provided a controlling electrode 31, connected through a loading resistance 32 to the next succeeding secondary cathode. By means of these controlling electrodes 31 portions of the standing current of the multiplier are diverted from the collector 28. When the total current increases beyond a predetermined value, depending mainly upon the value of the loading resistances, the potential drop across each of these resistances reduces the potential at the corresponding controlling electrode 31 to substantially the same potential as the following secondary cathode. Thus, there will be no further increase in the current diverted by the controlling electrodes 31 and any further increase in the primary electron emission from the photoelectric cathode 23 is faithfully reproduced in the output device 30. Thus, the amount of current flowing before appreciable output is obtained may be varied by adjusting the value of the load resistances 32 or by varying the number of controlling electrodes 31 which are employed.

The photoelectron multiplier shown in Figure 3 is particularly suitable for operating relays by small variations of light. Normally, in such apparatus the relay is liable to be operated by thermal emission from any of the cathodes or by stray light on the photoelectric cathode 23. The operation of the multiplier may be adjusted, for instance, by means of the load resistances 32 so that the operation of the relay only occurs after the primary current exceeds a given value. In the case where modulated light is to be received on the photoelectric cathode 23 tuned circuits may be placed in series with one or more of the controlling electrodes 31 so as to render the multiplier selective to light modulated at one frequency or band of frequencies. In this way, there is also obtained a reduction in the influence of any unmodulated light, such as daylight on the photoelectric cathode 23. Furthermore, the tuned load circuits may be shunt-circuited by a selective device, or devices, to eliminate individual modulation frequencies such, for example, as interference produced by the light from lamps lit from the normal alternating current mains supply. It will be seen that the controlling electrodes 31 also have the same function as the auxiliary electrodes 47 in providing, under operating conditions, a field of uniform potential between this electrode and the next following secondary cathode. Alternatively auxiliary electrodes 47 may be provided for all the secondary

cathodes 26 and controlling electrodes 31 may be employed where required in front of one or more of these auxiliary electrodes.

In Figure 4 there is shown a radio receiver employing a thermionic electron multiplier. The receiver is of the superheterodyne type and comprises a thermionic valve 33 for generating local oscillations in conjunction with a tuned anode circuit 34 and a grid coil 35 coupled therewith. The output of the local oscillator is applied between the primary thermionic cathode 36 of the multiplier and an earth line 37. The receiver has a tuned signal circuit 38 fed by an aerial coil 39 and coupled to a control grid 40 of the multiplier for controlling the primary emission from the thermionic cathode 36. The local oscillations and incoming signals are thus mixed at the control grid 40 to provide beat frequency signals. The primary electron stream is directed by the accelerator 24 on to the secondary cathode 25 employed in conjunction with succeeding secondary cathodes 26 and 27, and a collector 23, as in the case of the electron multiplier shown in Figure 3. Also, each of the secondary cathodes 26 is provided with an auxiliary electrode 47, as aforesaid. A controlling electrode 31 is provided in front of each of the last two secondary cathodes 26 and is connected through a parallel tuned circuit 41 and a series resistance 42 with the next following secondary cathode, so that each controlling electrode 31 has a potential higher than that of the secondary cathode immediately following it. The beat frequency output from the collector electrode 23 is applied by means of a tuned transformer coupling 43 to a rectifying diode 44 forming part of an output valve 45 for the rectified signals, the anode circuit of this valve being coupled through a transformer 46 to a loud-speaker.

Operating potentials for the electron multiplier are derived from a potential divider 43 for connection across one source of high tension supply and by a subsidiary high tension supply is applied to the secondary cathode 25 and is also utilised for the oscillator 33, and the output valve 45.

The beat frequency signals produced at the control grid 40 are amplified in the successive multiplier stages. The controlling electrodes 31 by reason of the high positive potentials applied to them, by-pass portions of the space current, depending upon the values chosen for the resistances 42. Furthermore, the tuned circuits 41 which are tuned to the beat frequency signals provide a high degree of selectivity, as described with reference to Figure 2. It will be appreciated that the receiving circuit associated with the multiplier may be considerably varied without departing from the invention, and in particular, the mixing of the incoming signals and local oscillations may be effected outside the electron multiplier and only the required beat frequency signals applied to the control grid 40 thereof.

It is usual to operate the secondary cathodes of electron multipliers with a potential difference of the order of 300 volts and such a potential difference is suitable in the case of the electron multiplier apparatus hereinbefore described.

The controlling electrode may be positioned immediately in front of a secondary cathode in an electron multiplier, or in front of a preceding auxiliary electrode as described with reference to Figure 4 or in between the secondary cathode and the associated auxiliary electrode, the controlling electrode having in each case a higher initial

potential applied to it than the secondary cathode, and any of the specific arrangements described above may be modified accordingly. Moreover the circuit of the controlling electrode may comprise frequency selective means for by-passing unrequired frequencies or for injecting signal frequencies into the space current without material potential dropping or including such resistance as required in any individual case for this purpose.

It will be understood that the invention is not restricted to the specific type of multiplier hereinbefore described with reference to the drawing, in which the secondary cathodes consist of grid or like members, but is also applicable to electron multipliers in which the secondary cathodes are formed of plates arranged either in two groups so that the electrons are caused to follow a zig-zag path from one electrode to the next, or are arranged in one group with deflecting means for causing the electrons to travel in a curved path from one electrode to the next.

I claim:

1. An electron discharge apparatus comprising an electron multiplier having a primary cathode and a plurality of positively charged electrodes comprising at least one secondary cathode and a collector, a by-passing electrode other than a collector anode provided adjacent said secondary cathode, a resistance connected to said by-passing electrode and means for applying to this by-passing electrode through said resistance a positive potential above zero which under conditions of no space current is of the same polarity with respect to the cathode as, but greater than that applied to the next following positively-charged electrode, the value of which resistance is so selected that the space current flowing by way of the by-passing electrode produces a potential drop across the resistance such that the by-passing electrode assumes a potential of the same order as that applied to the next following electrode.

2. An electron discharge apparatus comprising an electron multiplier having a primary cathode and a plurality of positively-charged electrodes comprising at least one secondary cathode and a collector, means for applying to said positively-charged electrodes positive potentials progressively increasing towards the collector, a by-passing electrode other than a collector anode positioned in front of said secondary cathode, a resistance connected between said by-passing electrode and the positively-charged electrode which follows said secondary cathode, and means for applying to said by-passing electrode through said resistance a positive potential above zero which under conditions of no-space current is of the same polarity with respect to the cathode as but greater than that applied to the next following positively-charged electrode, the value of which resistance is so selected that the space current flowing by way of the by-passing electrode produces a potential drop across the resistance such that the by-passing electrode assumes a potential of the same order as that applied to the next following electrode.

3. An electron discharge apparatus comprising an electron multiplier having a primary cathode and a plurality of positively-charged electrodes comprising at least one secondary cathode and a collector, means for applying to said positively-charged electrodes positive potentials progressively increasing towards the collector, a by-passing electrode other than a collector anode posi-

tioned in front of said secondary cathode, frequency selective means connected to the said by-passing electrode, a resistance connected between said by-passing electrode and the positively-charged electrode which follows said secondary cathode, and means for applying to said by-passing electrode through said resistance a positive potential above zero which under conditions of no-space current is of the same polarity with respect to the cathode as but greater than that applied to the next following positively-charged electrode, the value of which resistance is so selected that the space current flowing by way of the by-passing electrode produces a potential drop across the resistance such that the by-passing electrode assumes a potential of the same order as that applied to the next following electrode.

4. A photo-electric multiplier comprising a photo-electric cathode and a plurality of positively-charged electrodes comprising a plurality of secondary cathodes and a collector, means for applying to said secondary cathodes and collector positive potentials with respect to the primary cathode and of progressively increasing value towards the collector, a by-passing electrode positioned in front of at least one of said secondary cathodes, a resistance connecting the said by-passing electrode to a said positively-charged electrode following said secondary cathode, and means for applying to said by-passing electrode through said resistance a positive potential above zero which under conditions of no-space current is of the same polarity with respect to the cathode as but greater than that applied to the next following positively-charged electrode, the value of which resistance is so selected that the space current flowing by way of the by-passing electrode produces a potential drop across the resistance such that the by-passing electrode assumes a potential of the same order as that applied to the next following electrode.

5. An electron multiplier apparatus comprising a thermionic primary cathode, an input electrode, means for applying signal potentials to said input electrode, a plurality of positively-charged electrodes comprising a plurality of secondary cathodes and a collector, means for applying to said positively-charged electrodes positive potentials which are of increasing value towards the collector, a by-passing electrode positioned in front of at least one of said secondary cathodes, tuned circuit signal selective means connected to said by-passing electrode, a resistance connected in series between said by-passing electrode and the positively-charged electrode following said secondary cathode, a signal output device connected to said collector, and means for applying to said by-passing electrode through said resistance a positive potential above zero which under conditions of no-space current is of the same polarity with respect to the cathode as but greater than that applied to the next following positively-charged electrode, the value of which resistance is so selected that the space current flowing by way of the by-passing electrode produces a potential drop across the resistance such that the by-passing electrode assumes a potential of the same order as that applied to the next following electrode.

6. An electron discharge apparatus comprising an electron discharge device having a cathode and at least one cooperating electrode positively charged with respect to the cathode, a by-passing electrode other than a collector anode in the

space current path of said discharge device, a resistance connected to said by-passing electrode, means for applying to said by-passing electrode through said resistance a potential which under conditions of no-space current is positive with respect to the next succeeding positively charged electrode, the values of which resistance and of the potential applied to it under no-space current conditions are so selected that at a predetermined value of space current there is a drop of potential through the resistance caused by the by-passed space current, so that the potential of the by-passing electrode becomes the same as that of the succeeding electrode.

7. An electron discharge apparatus comprising an electron discharge device having a cathode and at least one cooperating electrode positively charged with respect to the cathode, a by-passing electrode other than a collector anode in the space current path of said discharge device, an impedance connected to said by-passing electrode, means for applying to said by-passing electrode through said impedance a potential which under conditions of no-space current is positive with respect to the next succeeding positively charged electrode, the values of which impedance and of the potential applied to it under no-space current conditions are so selected that at a predetermined value of space current there is a drop of potential through the impedance caused by the by-passed space current, so that the potential of the by-passing electrode becomes the same as that of the succeeding electrode.

8. An electron discharge apparatus comprising an electron discharge device having a cathode and at least one cooperating electrode positively charged with respect to the cathode, a by-passing electrode other than a collector anode in the space current path of said discharge device, a resistance and impedance connected to said by-passing electrode, means for applying to said by-passing electrode through said resistance and impedance a potential which under conditions of no-space current is positive with respect to the next succeeding positive charged electrode, the values of which resistance and impedance and of the potential applied to them under no-space current conditions are so selected that at a predetermined value of space current there is a drop of potential through the resistance caused by the by-passed space current so that the potential of the by-passing electrode becomes the same as that of the succeeding electrode.

9. An electron discharge apparatus comprising an electron discharge device having a cathode and at least one cooperating electrode positively charged with respect to the cathode, a by-passing electrode other than a collector anode in the space current path of said discharge device, frequency-selective means and a resistance connected to said by-passing electrode, means for applying to said by-passing electrode, through said resistance, a potential which under conditions of no-space current is positive with respect to the next succeeding positively charged electrode, the values of which resistance and of the potential applied to it under no-space current conditions are so selected that at a predetermined value of space current there is a drop of potential through the resistance caused by the by-passed space current, so that the potential of the by-passing electrode becomes the same as that of the succeeding electrode.

10. An electron discharge apparatus comprising an electron discharge device having a pri-

mary cathode, a plurality of positively charged electrodes, including at least one secondary cathode and a collector, a by-passing electrode in the space current path of said discharge device, an impedance connected to said by-passing electrode, means for applying to the by-passing electrode through said impedance a potential which under conditions of no-space current is positive with respect to the next succeeding positively charged electrode, the values of which impedance and of the potential applied to it under no-space current conditions are so selected that at a pre-determined value of space current there is a drop of potential through the impedance caused by the by-passed space current, so that the potential of the by-passing electrode becomes the same as that of the succeeding electrode.

11. An electron discharge apparatus comprising an electron multiplier having a primary cathode and a plurality of positively charged electrodes, including at least one secondary cathode,

and a collector, means for applying to said positively charged electrode positive potentials progressively increasing towards the collector, a by-passing electrode positioned in front of said secondary cathode, an impedance connected between said by-passing electrode and the positively charged electrode which follows said secondary cathode, means for applying to said by-passing electrode through said impedance a potential which under conditions of no-space current is positive with respect to the next succeeding positively charged electrode, the values of which impedance and of the potential applied to it under no-space current conditions are so selected that at a pre-determined value of space current there is a drop of potential through the impedance caused by the by-passed space current, so that the potential of the by-passing electrode becomes the same as that of the succeeding electrode.

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