Jan. 30, 1940. A. A. LINSELL 2,188,410

ELECTRON MULTIPLIER

Filed Sept. 30, 1937 2 Sheets-Sheet 1

Fig. 1

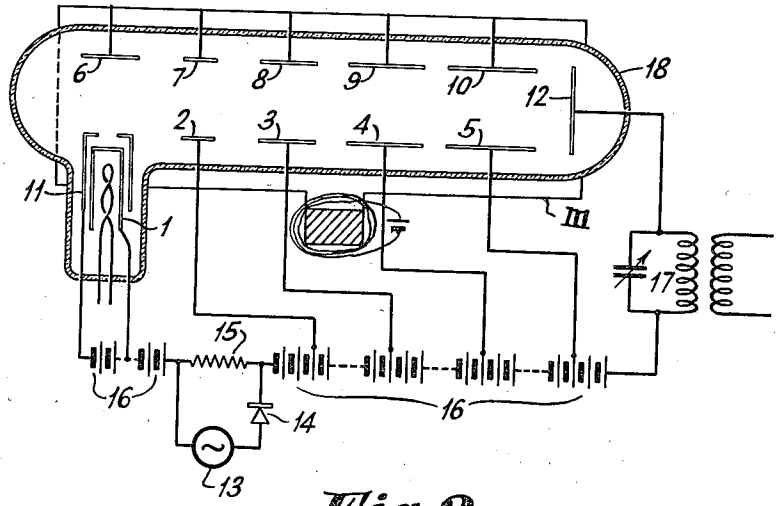


Fig. 2

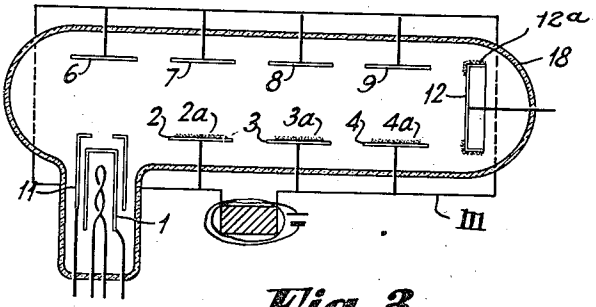
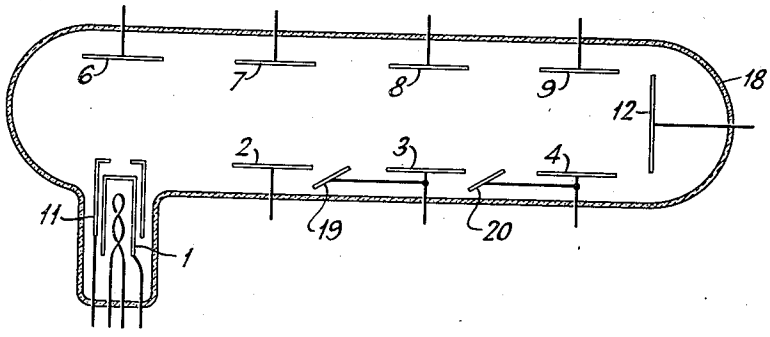


Fig. 3



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Filed Sept. 30, 1937 2 Sheets-Sheet 2

Fig. 4

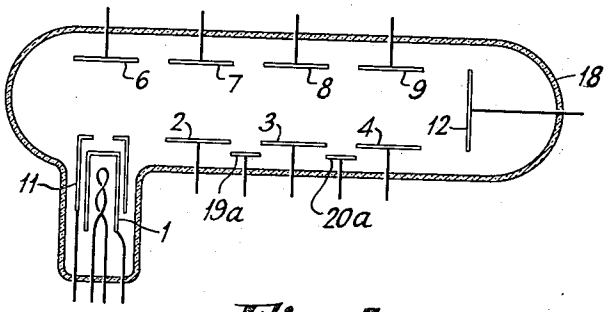


Fig. 5

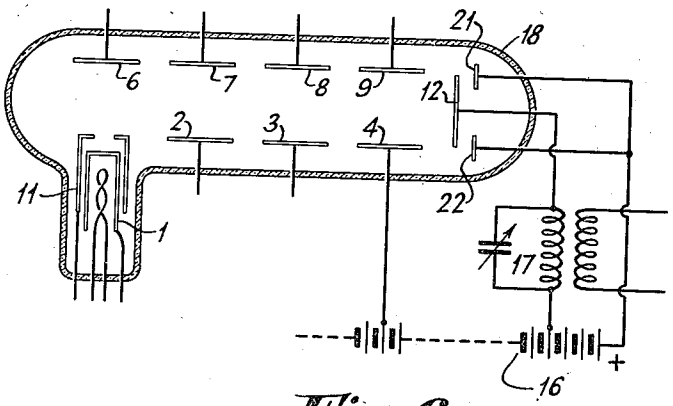
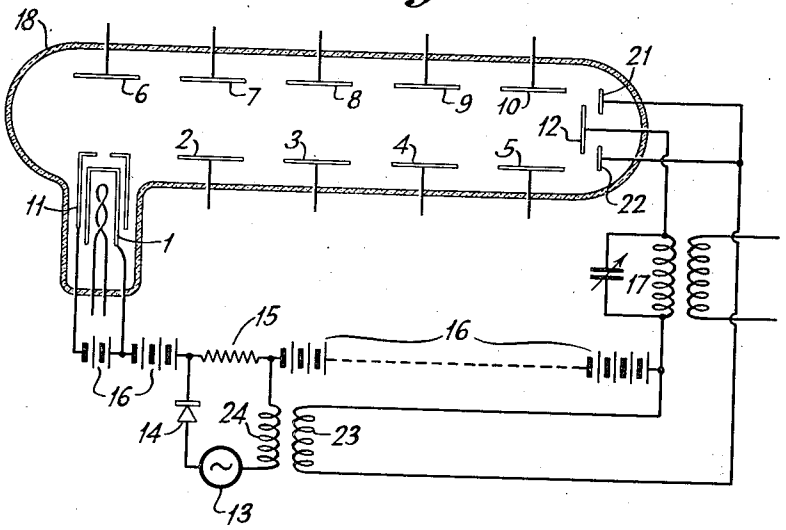


Fig. 6



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2,188,410

UNITED STATES PATENT OFFICE

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ELECTRON MULTIPLIER

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Application September 30, 1937, Serial No. 166,491
In Great Britain October 26, 1936

6 Claims. (Cl. 250—175)

This invention relates to electron discharge devices and more particularly to electron discharge devices of the electron multiplier type in which a primary electron current derived from a thermionic, photo-electric, or other primary cathode is amplified or multiplied one or more times by secondary electron emission.

A known form of electron multiplier, such as is disclosed in U. S. Patent 2,073,599, Malter, and in which the present invention may be embodied, comprises in general a primary cathode, a row of secondary emitters, a parallel row of accelerating electrodes, and an output anode. The accelerating electrodes and the secondary electron emitters are at positive potentials which increase toward the output anode and a magnetic field causes the stream of electrons from the cathode to bombard the first secondary emitter, the resulting stream of secondary electrons to bombard the second emitter, and so on, electron multiplication occurring at each bombardment. Such an electron multiplier has an accelerating voltage-final output current characteristic curve, which over a range of accelerating voltage from zero to about 600 volts between emitters rises to a maximum of about 300 volts and then falls away again, showing a pronounced though not very sharp peak.

The principal object of the invention is to provide an improved electron multiplier useful for frequency multiplication, particularly frequency doubling, and similar purposes. Another object of the invention is to provide an electron multiplier having improved properties and characteristics, especially a characteristic curve in which the sharpness of the peak is substantially increased. A further object is to provide a simple frequency doubler in which the improved electron multiplier is utilized.

According to the invention at least one of the electrodes of the electron multiplier is so dimensioned or constructed that with an increase in the accelerating voltage beyond a predetermined critical value at which the output current is a maximum and at which the multiplier is normally operated, the proportion of electrons in one or more of the electron streams which is utilized to contribute to the generation of secondary electrons and to the final output current substantially decreases so that the output current falls sharply with the increase in operating voltage beyond the critical or normal value and the peak in the characteristic curve is sharpened. Owing to the peak in the characteristic curve, the electron multiplier may, in accordance with the invention, be used for frequency multiplication, particularly frequency doubling, and to this end the electron multiplier is operated at an accelerating voltage near the value corresponding to the summit of the peak and the positive half waves of a frequency which is to be doubled is superimposed upon the accelerating voltage. The increase in potential during each half wave will cause the output current first to increase to the maximum and then to decrease with the further increase in potential so that a complete output cycle will be obtained from one-half of the input wave. Similarly, the negative half cycles of input energy can be dealt with in the same way by operating the tube at an accelerating voltage near but on the other side of the summit of the peak.

For a better understanding of my invention, reference may be had to the accompanying drawings in which some embodiments of the invention are illustrated diagrammatically, and in which Figure 1 shows one form of multiplier used as a frequency doubler, Figures 2, 3, 4 and 5 show modifications, and Figure 6 shows a modification used as a frequency doubler.

One way of carrying out the invention is illustrated in the accompanying Figure 1 showing a known type of electron multiplier comprising an indirectly heated primary cathode 1 with a control electrode 11, a row of secondary emitter electrodes 2, 3, 4, and 5, a parallel row of accelerating electrodes 6, 7, 8, 9, and 10 in a plane parallel to the plane of the emitters, and an output anode 12. The multiplier is connected in the usual way to a source 16 of operating potential, and if used for frequency doubling is also connected to a source of alternating voltage 13, a rectifier 14, a resistance 15, and a tuned load circuit 17. In use, the accelerating electrodes 6 to 10 are maintained at increasingly positive potentials in the usual way, not shown; for example, each accelerating electrode may be connected internally of the envelope 18 to the next secondary emitting electrode so that electrode 6 is connected to emitter 2, electrode 7 to emitter 3, and so on, as shown in the patent above mentioned, which also shows a magnetic field system which may be used such as the magnetic system M.

In accordance with the invention this conventional electron multiplier is modified by making the accelerating electrodes and the secondary emitters not, as hitherto, all of the same size, but of graduated size. As shown in Figure 1 these electrodes, except the accelerating electrode 6, are of greater size as their distance from the

primary cathode 1 increases. At each step of electron multiplication, the electron beam becomes progressively larger in cross-section, hence the graduation of size in electrodes 2 to 5 and 7 to 10 may be a graduation in length or in width, or both. Constructing the tube in accordance with this invention with electrodes of increasing size insures that the electron beams will just cover the emitters at normal operating voltage and will tend to overshoot their targets or overflow the edges of the emitters when a critical potential, slightly above normal operating voltage and the same for all the beams, is reached. In this way the peak of the characteristic at the critical voltage is considerably sharpened.

In another construction shown in Figure 2 the multiplier of Figure 1 is modified in accordance with this invention by the use of multiplying electrodes or emitters 2, 3, and 4, which are of the same size, but are rendered secondary electron emitting, not over their whole surfaces, but over areas smaller than the whole surfaces. These areas, indicated at 2*a*, 3*a*, and 4*a*, are coated with a secondary electron emitting material, such as caesium compounds and are graduated in size, increasing with distance from the cathode 1 and with proximity to anode 18. When the electron beams increase in cross section with increasing voltage, the proportion of electrons in the beams which strike the coated or electron emitting areas is reduced. As also indicated in this figure, the peak of the characteristic may be exaggerated by coating the peripheral area of the output anode with a secondary electron emissive coating 12*a*.

In another modification shown in Figure 3 the emitters 2, 3 and 4 and the accelerating electrodes 6, 7, 8 and 9 are of the same size but adjacent each secondary emitter or multiplying electrode except the last and, for example, adjacent each emitter 2 and 3 is an auxiliary electrode 19 between the corresponding emitter and the output anode. Each auxiliary electrode 19 is preferably tilted somewhat so as to face partly toward the accelerating electrode opposite the corresponding secondary emitter electrode to which the auxiliary electrode is adjacent. Each auxiliary electrode is connected to the next secondary emitter in the series, the first auxiliary electrode 19 being connected to emitter 3 and the second to emitter 4. In a multiplier of this construction, increasing the accelerating potential beyond a predetermined critical value causes increasing proportions of the electrons in the electron streams to fall upon the auxiliary electrodes and thus not contribute to further secondary emission.

As illustrated in Figure 4, the auxiliary electrodes marked 19*a*; 20*a* in this figure may, instead of being slightly tilted, be positioned between successive secondary emitter electrodes and somewhat behind them, so as to be further away than the emitters from the plane of the accelerating electrodes. If desired, the auxiliary electrodes may, as indicated in Figure 4, be provided with separate external connections to enable the applied potentials to be individually adjusted.

In a further modification illustrated in Figure 5 the peak in the characteristic curve is exaggerated by the use of auxiliary electrodes 21, 22 in the form of small plates placed behind and beside the output anode 12. These auxiliary electrodes are connected to a source of higher potential than the output anode. In this modification the size of the output anode 12 is critically chosen in dependence upon the point at which the peak of the characteristic curve is required to occur, so that at the critical accelerating voltage all the discharge reaches the output anode. When the accelerating voltage corresponding to this peak is exceeded the cross section of the discharge becomes greater than the area of the output anode 13, and an increasing number of the electrons miss and overflow the edge of the output anode and are taken up by the auxiliary electrodes 21, 22.

An electron multiplier as described may be employed as a frequency multiplier by superimposing upon the usual accelerating potentials applied to the various electrodes a unidirectional potential derived by rectifying alternating current voltage of a frequency to be doubled, as shown in Figure 1. For this purpose the source 13 of the alternating voltage to be doubled is connected in series with the rectifier 14 across the resistance 15 inserted in series with the operating potential source 16 for the electrodes, the place of insertion being so chosen that the unidirectional superimposed potential is superimposed on all the electrodes to which the operating source 16 is connected. The output anode is connected in the usual way to the positive terminal of the potential source 16, preferably through the parallel tuned circuit 17 resonant to a frequency double the frequency of the source 13.

If the modification shown in Figure 5 is used for frequency doubling, the auxiliary electrodes 21, 22 may, as shown in Figure 6, be connected together and through a coil 23 to the positive terminal of the operating potential source 16, this coil being coupled to a coil 24 which is connected in series with a rectifier 14 and also a source of frequency 13 to be doubled across a resistance 15 inserted in series with the operating potential source 16. The output circuit includes a tuned output circuit 17 tuned to double the frequency of the source 13. The arrangement is such that the circuit in which the auxiliary electrodes 21 and 22 are connected is back coupled to the input circuit, this back coupling tending to exaggerate the peak in the characteristic. In order to indicate that the invention is not limited to the use of any particular number of electron multiplier stages one more stage is shown in Figures 1 and 6 than in the other figures, the extra accelerating electrode being marked 10 and the extra emitter 5.

I claim:

1. An electron multiplier comprising a primary cathode, an output anode, a pair of opposed electrodes on opposite sides of the path of the electron stream from said cathode to said anode, one of said electrodes comprising a metal sheet positioned to intercept said stream and having a coating of high secondary electron emissivity smaller than said metal sheet and of substantially the size of the cross-section of said electron stream to said electrode at the critical accelerating voltage at which maximum output of the multiplier occurs.

2. An electron multiplier comprising a primary cathode, an output anode, a row of emitter electrodes between said cathode and said anode, accelerating electrodes in a plane parallel to the plane of said row of emitters and adapted to be connected to a source of operating voltage, said emitters being coated over areas graduated to increase in size in the direction of the output anode

with material having secondary electron emission greater than unity at normal operating voltage to provide active surfaces no greater in size than the cross-section of the electron discharge which impinges on said emitters at the critical operating voltage at which maximum output of the multiplier occurs.

3. An electron multiplier as defined in claim 1 in which the peripheral area of the output anode is coated with electron emissive material.

4. An electron multiplier comprising a primary cathode, an output anode, a pair of opposed electrodes on opposite sides of the path of the electron stream from said cathode to said anode, one of said electrodes being positioned to intercept said stream and comprising a metal sheet having an oxide coated secondary emissive portion of no greater size than the electron stream which impinges on said electrode at the critical accelerating voltage at which maximum output of the multiplier occurs and a non-emissive conductive metal portion adjacent the edge of said oxide coated portion for collecting the part of said electron stream which overflows said coated portion.

5. An electron multiplier comprising a primary cathode, an output anode, a row of emitter electrodes between said cathode and said anode, a row of discrete accelerating electrodes in a plane parallel to the plane of said row of emitters and adapted to be connected to a source of operating voltage, one of said emitters comprising an oxide coated metal surface of high secondary emissivity no greater in area than the cross-section of the electron discharge which impinges on said emitter at the critical operating voltage at which maximum output of the multiplier occurs, and a clean metal surface adjacent the edge of said oxide coated surface and in the path of that part of the electron discharge which passes the edge of said oxide coated surface.

6. An electron multiplier comprising a primary cathode, an output anode, a row of discrete accelerating electrodes between said cathode and said anode and adapted to be connected to a source of operating voltage, a row of emitter electrodes in a plane parallel to the plane of said row of accelerating electrodes, each emitter electrode comprising an oxide coated emitter portion and a non-emitting conductive portion positioned adjacent and extending beyond the edge of the oxide coated portion to intercept and collect that part of the discharge which misses said oxide coated portion of said emitter at an accelerating voltage higher than the critical value at which maximum output of the multiplier occurs.

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