June 10, 1941. G. B. BANKS 2,245,174

ELECTRON DISCHARGE DEVICE

Filed March 16, 1937

Fig. 1

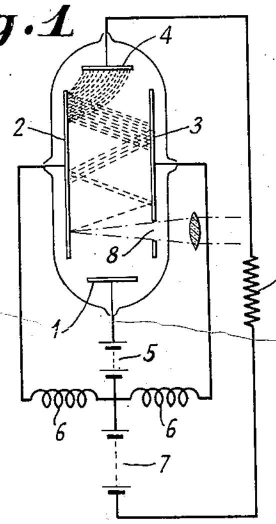


Fig. 2

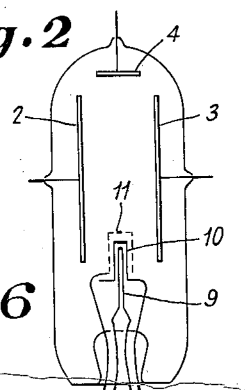


Fig. 6

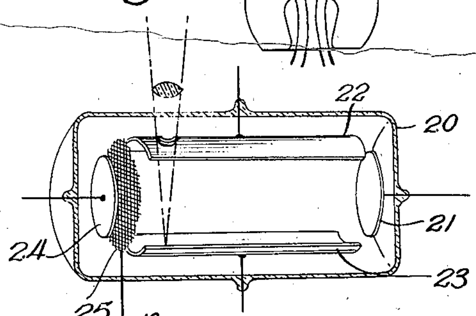
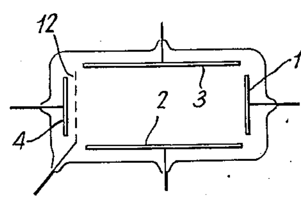


Fig. 3



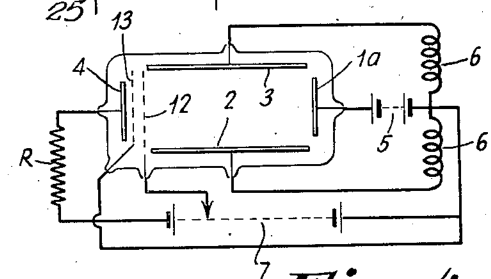
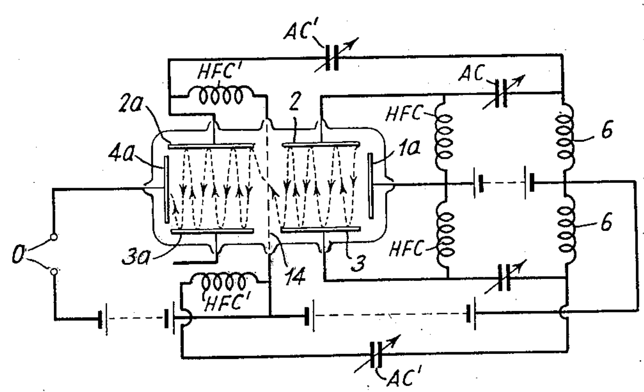


Fig. 4

Fig. 5



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ELECTRON DISCHARGE DEVICE

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3 Claims. (Cl. 250—175)

This invention relates to electron discharge devices and more particularly to electron discharge devices of the electron multiplier type, i. e. of the type wherein a primary electron stream from a primary source of electrons, e. g. a photosensitive cathode or a thermionic cathode is magnified or amplified in one or more steps by utilizing the phenomenon of secondary emission.

The object of the present invention is to provide an improved electron multiplier of simple construction and arrangement which does not require the use of more or less complex beam concentrating structures or comparatively high operating potentials and which is such that control of the overall amplification within wide limits may be easily obtained.

According to this invention an electron multiplier arrangement comprises two elongated oppositely disposed electrodes which face one another and are both capable of secondary emission, a source of primary electrons, means for applying a high frequency alternating electrostatic field between said oppositely disposed electrodes, and means including an output electrode for applying a uni-directional electrostatic field having a component at right angles to the said alternating field, the arrangement being such that electrons from the source travel to one of the oppositely disposed electrodes causing secondary emission which travels to the other of the two oppositely disposed electrodes where further secondary emission is caused to travel to the first of said two oppositely disposed electrodes, and so on, until finally, as a result of the uni-directional electrostatic field, secondary electrons from one of said oppositely disposed electrodes reach the output electrode.

The invention is illustrated in and further explained in connection with the accompanying drawing, in which

Fig. 1 shows one embodiment of my invention,

Fig. 2 shows an embodiment thereof using a thermionic cathode,

Fig. 3 is a modification wherein a screen grid is incorporated,

Fig. 4 is a modification showing the use of both screen and suppresser grids,

Fig. 5 is a multi-stage multiplier, and

Fig. 6 schematically represents a further modification of the invention.

Referring first to Fig. 1 the tube therein shown has within an evacuated envelope two elongated plate-like electrodes **2**, **3** disposed opposite and parallel to one another, one of said electrodes (the electrode **3**) having an aperture **8** near one end. Both the electrodes **2**, **3** are prepared or coated with a material of low work function, for example caesium, so as to be capable of secondary emission. The envelope also contains two further plate-like electrodes **1**, **4** which are also opposite and parallel to one another, a line drawn between and normal to the electrodes **1**, **4**, being at right angles to a line joining and normal to the electrodes **2**, **3**. The said electrodes **1**, **4**, are, as shown, one at or near one end of the envelope and the other at or near the other. One of the said electrodes **1**, **4**—the electrode **4**—acts as the output electrode and in use is connected through an output impedance R in series with a source **7** of D. C. potential to the other of the two said electrodes **1**, **4**, the output electrode (**4**) being, of course, positive. Alternating potentials are applied from a source (not shown) between the electrodes **2**, **3**, e. g. by means of a transformer having a centre tapped secondary **6** (the primary is not shown) connected between the two electrodes in question, the centre tapping being connected to the negative terminal of the potential source **7** and through a source **5**, to the electrode **1**. The sources **5**, **7**, are in series and may be constituted by a single battery or the like. In use a beam of light is projected as indicated through the aperture **8** in the electrode **3** so as to fall upon the opposite electrode **2**, the point or area of incidence of the beam on said electrode **2** being suitably prepared so that said point or area acts as a photoelectric cathode. Photoelectrons will accordingly be emitted. The amplitude and frequency of the alternating potential applied—the frequency will be a radio frequency—are so regulated that the time taken by an electron to travel from one of the two secondary emitting plates **2**, **3** to the other is equal to one half cycle. Accordingly, photoelectrons emitted will travel to the opposite electrode and the resultant secondary electrons (which will exceed in number the primary electrons whereby they are released—they may, in fact, be from five to ten times as many) will travel back to the first electrode (giving still further electron multiplication by secondary emission) and so on, and owing to the uni-directional field between the electrodes **1**, **4**, the electron paths will be oblique, i. e. the electrons will "travel up" the two secondary emitting electrodes until finally secondary electrons from one of the said electrodes will reach the output electrode. The electron paths are conventionally indicated in Fig. 1. As will be appreciated the number of electrons collected by the output electrode **4** will be dependent upon the number of times the electrons travel between the two secondary emitting electrodes **2**, **3** and accordingly, therefore, by adjusting the uni-directional field between the electrodes **1**, **4**—obviously a very simple matter—the overall amplification can be regulated.

In a modification, described hereinafter in Fig. 6, in order to ensure that electrons shall not escape from between the secondary emitting electrodes until the output electrode is reached, the said secondary emitting electrodes instead of being of flat plate form are curved so as to be of part cylindrical form, that is to say, each of the said electrodes in section embraces a part of a common circle, the two parts being equal and symmetrically placed. In this way a concentrating effect on the electrons is obtained owing to the share of the lines of the electrostatic field.

In the embodiments above described the primary source is photoelectric but this is not a necessary feature of the invention, for a thermionic primary source may be used, if desired. For example, in a modification well adapted for the amplification of weak potentials and illustrated in Fig. 2 the electrode **1** of Fig. 1 is replaced by an electrode structure comprising a thermionic cathode **10** (as shown an indirectly heated cathode heated by a heater **9**) of elongated form and closely surrounded by a cylindrical control or grid-like electrode **11**, the axis of the grid like electrode and of the cathode pointing towards the output electrode. In this case, of course, the aperture **8** is dispensed with. The tube of Fig. 2 is not shown in circuit but it may obviously be used in a circuit like that of Fig. 1.

The wave form of the alternating current potential applied between the two secondary emitting electrodes **2**, **3** of Figs. 1 and 2 may be varied within wide limits but a considerable advantage will be obtained if this wave form, instead of being sinusoidal, is square topped. Such a square topped wave form may be obtained in various well known ways, for example, by means of a so-called "multivibrator."

It should be noted that the effective cathode anode impedance or internal effective resistance of a tube as shown in Fig. 1 or 2 is normally negative and advantage may be taken of this fact to secure large amplification by employing an output external impedance R (see Fig. 1) of resistance numerically nearly equal to the internal resistance. The amplification is a constant multiplied by a fraction equal to the external anode resistance divided by the algebraic sum of said resistance and the interal resistance.

If—for example for reasons of stability—a negative internal resistance is deemed undesirable a positive internal resistance may be obtained by providing a screen grid in front of the anode (**4**). Again, if desired, a suppressor grid may be incorporated. Where a screen grid is employed it is, in use, positively biased.

Fig. 3 shows a modification wherein a screen grid is incorporated, the screen grid being marked **12**. The tube of Fig. 3 is like that of Fig. 1 except for the provision of the screen grid and the fact that the aperture **8** (of Fig. 1) is omitted, the electrode **1a** opposite the electrode **4** of Fig. 3 being a photosensitive primary cathode.

Amplification of the order of 1000 is obtainable with a tube as shown in Fig. 1 or 2, but attempts to increase this amplification tend to result in instability owing to the negative internal resistance presented by the tube. For instance, with a resistive anode load, an increase in anode current produces a decrease in anode voltage (due to the increased voltage drop across the anode load) and this in turn produces an increase in anode current due to the increased number of electron traversals between electrodes **2** and **3** consequent upon decreased anode voltage. The provision of a screen grid (for example, as shown in Fig. 3) between the anode and the multiplier electrodes **2**, **3** avoids this defect or limitation. This screen grid when suitably positively biased, substantially prevents the above undesired effect of change of anode voltage upon amplification or magnification.

In order to prevent any secondary emission there may be from the anode from reaching the screen grid when the potential of the former falls below that of the latter an earthed suppressor grid **13** may be provided, as shown in Fig. 4 between the screen grid **12** and the anode **4**. Except for the provision of this suppressor grid the tube of Fig. 4 is like that of Fig. 3 and except for the provision of connections for the grids **12** and **13** the circuit of Fig. 4 is like that of Fig. 1.

Figure 5 shows what is, in effect, a two stage multiplier in accordance with this invention. Here there is a primary cathode **1a** (shown as a photo-sensitive plate) two secondary emitter electrodes **2**, **3**, and a first anode **14** which cooperate in much the same way as do the electrodes **1**, **2**, **3** and **4** of Fig. 1. The first anode **14** is, however, not a plate but a wide mesh electrode through which electrons pass into the second stage which includes further secondary emitter electrodes **2a**, **3a**, and a final output anode **4a**. The pairs **2**, **3** and **2a**, **3a**, of secondary emitter electrodes are supplied with high frequency voltage via a transformer secondary **6** and small adjustable condensers AC, AC'. Chokes HFC connect the plates **2**, **3**, to the cathode **1a** and chokes HFC' connect the plates **2a**, **3a**, to the electrode **14**. The electrode **4a** is maintained at about twice the potential of the electrode **14** and output may be taken off at the terminals marked O. Obviously, the cascading of the stages results in increased magnification; for example, if the magnification of each stage taken separate is 1000, the overall magnification should be (theoretically) 10^6. If desired, more than two stages may be provided in cascade in the one envelope; for example, the electrode **4a** of Fig. 5 might be replaced by a second mesh electrode like the electrode **14** and a further electrode system, like the system **2a**, **3a**, **4a**, provided to handle electrons passed therethrough.

Obviously, in all the embodiments any other suitable means for applying the high frequency input may replace the transformer having the secondary **6**.

Referring to Fig. 6, there is schematically shown a perspective view with a portion of the envelope cut away of a tube with concave electrode members. In this figure, the envelope **20** has positioned at one end thereof an electrode **21** which is mounted substantially perpendicular to the major axis of the concave electrode members **22** and **23**. At the end of the tube remote from the electrode **21** is a further electrode member **24**, and positioned between the latter electrode and the concave electrode members is a screen or mesh grid **25**.

What I claim is:

1. An electron multiplier comprising at least one pair of concave secondary electron emitting

members, the members forming a pair thereof being positioned with the concave faces thereof opposite to each other, electrode means positioned substantially perpendicularly to the major axis of said members comprising the electrode pairs and being adapted when energized to establish an electrostatic field substantially parallel to said major axis and to act as a collector means, there being means for initiating an electron flow toward one of the members of each electrode pair, and means positioned between said collector means and said electrode pairs for establishing in said multiplier a positive resistance value.

2. An electron multiplier comprising at least one pair of secondary electron emitting members, the members forming a pair thereof being positioned opposite to each other, electrode means positioned substantially perpendicularly to the major axis of said members comprising the electrode pairs and being adapted when energized to establish an electrostatic field substantially parallel to said major axis and to act as a collector means, there being means for initiating an electron flow toward one of the members of each electrode pair, means positioned between said collector means and said electrode pairs for establishing in said multiplier a positive resistance value, and a suppressor grid positioned adjacent said latter means.

3. An electron multiplier comprising at least one pair of secondary electron emitting members, the members forming a pair being positioned opposite each other and parallel therewith, said pairs all being positioned in parallel relationship, there being means for initiating an electron flow toward one of the members of each pair, collector electrode means positioned at an angle with respect to each of the pairs of electrodes, and an apertured electrode member positioned between each of said pairs of electrodes.

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