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ELECTRON DISCHARGE APPARATUS

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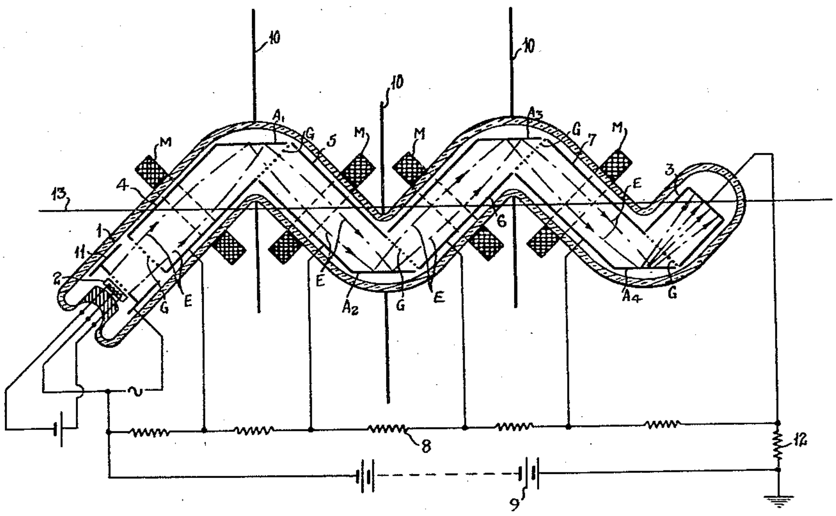

Fig. 1.

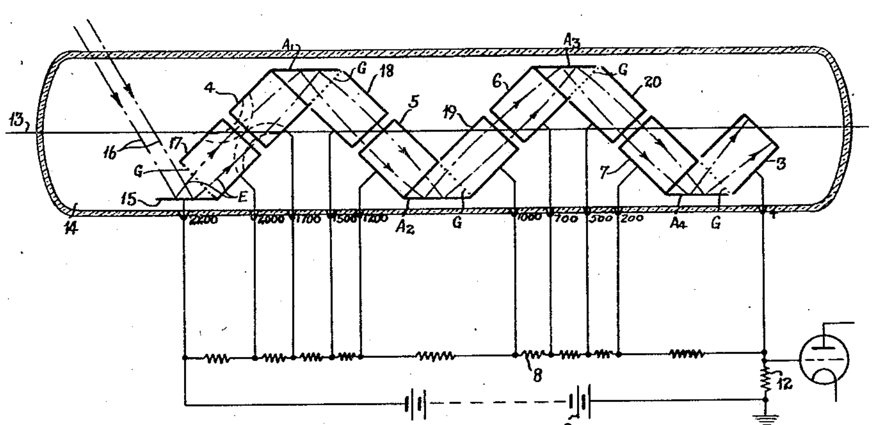

Fig. 2.

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## ELECTRON DISCHARGE APPARATUS

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23 Claims. (Cl. 250—174)

The present invention relates to electron discharge amplifiers.

It has been proposed to utilise secondary electron emission to give an amplifying effect in photo-electric devices. For this purpose there has been provided in a photo-electric tube an anode made of mesh material and a secondary cathode arranged on the opposite side of the anode to the normal photo-electric cathode. The anode and secondary cathode are maintained at positive potentials relatively to the photo-electric cathode, the potential of the anode being higher than that of the secondary cathode. Photo-electrons from the photo-electric cathode are accelerated towards the anode and may pass therethrough, due to its mesh construction, and strike the secondary cathode where they release secondary electrons many of which are attracted to the anode which is at a higher potential than the secondary cathode. The electron current to the anode is found with this arrangement to be greater than that obtained with an unperforated anode due to photo-electrons alone.

Since in this arrangement the secondary electrons return from the secondary cathode to the anode along the path of the arriving photo-electrons, it is not possible to obtain more than a single stage of amplification.

It has also been proposed to provide an amplifier operating by secondary emission to provide a plurality of stages of amplification. For this purpose a plurality of anodes of cylindrical or frusto-conical form are arranged co-axially one behind the other. The anodes are given progressively higher potentials proceeding from the co-operating cathode. In the case of the frusto-conical anodes the large diameter ends face the cathode.

With this arrangement electrons from the cathode are accelerated towards the nearest anode and some of these electrons strike the anode and release secondary electrons therefrom. These secondary electrons are accelerated towards the second anode and those which strike it liberate tertiary electrons therefrom and so on. The final anode may have a closed end so that it serves to collect the arriving electrons.

This known arrangement, in contradistinction to that first referred to, permits multi-stage amplification because the secondary electrons developed in one stage are drawn into the next stage out of the path of the primary electrons in the former stage.

However, although the electrostatic field between the successive anodes acts satisfactorily as an accelerating field, it tends to concentrate the electrons towards the axis of the anodes and thus to reduce the number of electrons striking the anodes. The electrodes developing these electrostatic fields are in effect electron lenses.

It is the principal object of the present invention to make use of secondary emission to provide an improved amplifier capable of high amplification.

According to the present invention there is provided an electron discharge amplifier of the kind adapted to produce current amplification by the impact of electrons upon a suitable target causing the emission of a greater number of electrons from said target, the last named electrons not returning along the path of the arriving electrons, the amplifier being characterised in that means are provided for producing a concentrating effect upon the electron stream between an electron source and the target from which electrons are to be emitted by impact, the concentrating means serving in increase the number of electrons from said source reaching said target.

The present invention also provides an electron discharge amplifier comprising a source of electrons, a target adapted to receive electrons from said source and, upon impact of these electrons, to emit secondary electrons and an electrode for receiving these secondary electrons, wherein the arrangement is such that the source of electrons and said electrode are disposed upon one side of a straight line and said target is disposed upon the opposite side of said straight line so that the electron path followed by electrons from the source proceeding to the target and that followed by secondary electrons from said target proceeding to said electrode is in the form of a zig-zag crossing and re-crossing said straight line.

Other features of the invention will be apparent from the following description and the appendant claims.

The invention will be described by way of example with reference to the accompanying drawing, in which Figs. 1 and 2 show diagrammatically two examples of apparatus according to the invention.

Referring to Fig. 1, an evacuated glass envelope **1** is bent into zig-zag form and has arranged in one end a cathode **2** which in the example shown is of the indirectly heated type. At the corners of the tube are arranged anodes or targets $A_1$, $A_2$, $A_3$ and $A_4$ and at the end of the tube opposite that containing the cathode is arranged an output electrode **3**. The space within the tube is substantially completely surrounded by screening members **4**, **5**, **6** and **7** which may take the form of metal cylinders within the tube or metallic coatings upon the inner walls of the tube.

The targets $A_1$—$A_4$ and the output electrode **3** are maintained respectively at progressively increasing potentials with respect to the cathode **1**. The screens **4**, **5**, **6** and **7** may be connected as shown to the targets adjacent their ends further from the cathode so that the screen and the connected targets are at the same potential. Alternatively the screens may be insulated from the targets and maintained at different potentials, preferably intermediate the potentials of the electrodes upon either side thereof. The required potentials are derived from a potential divider 8 arranged in parallel with a source 9.

Around the screens 4, 5, 6 and 7 are arranged coils M adapted to be energised from a suitable current source (not shown). Between adjacent coils M are arranged screens 10 for screening the coils M magnetically from one another.

If desired the ends of some or all of the screens 4, 5, 6 and 7 may be covered with grids or a series of wires as indicated at G. In operation, primary electrons from the cathode source 2 are accelerated towards the target $A_1$ by the electric field between the anode $A_1$ and screen 4 (and the grid G if provided), on the one hand, and the cathode 2 (and the electrode 11 which will be referred to later if this is used). A concentrating effect upon the primary electrons is also exercised by the magnetic field of coil M which surrounds their path, so that the trajectories are somewhat curved as indicated by the lines E. Because of the presence of the concentrating means in the form of the coils M, a greater number of electrons are directed upon the target $A_1$ and the striking of the tube walls by electrons is reduced.

The electrons strike the target $A_1$ with a velocity $V_1$ equal to the potential difference between the target $A_1$ and the source 2. This velocity is so chosen in relation to the material of which the target is composed that each primary electron liberates a plurality of secondary electrons. These secondary electrons are accelerated away from the path of the primary electrons towards the target $A_2$ by the electric field between target $A_1$ and the shield 5 and target $A_2$. The target $A_1$ thus constitutes a source of electrons with respect to target $A_2$ and the procedure is as described in connection with the primary electrons.

The electrons liberated from the target $A_4$ are accelerated towards and collected by the output electrode 3 which is formed as a Faraday cage so that no secondary electrons can escape therefrom. The electron current to this output electrode, which can be made much greater than the original primary emission current from the cathode, passes through an output impedance 12.

If it is desired to use the device to amplify electrical variations, these variations may be applied to a control electrode 11 which controls the number of primary electrons passing to the target $A_1$ in accordance with the applied potential variations. Amplified and corresponding potential variations then appear across the output impedance 12.

It will be observed that the electron path from the cathode 2 to the output electrode 3 is of zig-zag form and crosses and re-crosses the centre line 13 of the device. With this arrangement, therefore, any desired number of stages of amplification can be used and the concentrating means can be arranged to ensure that a large proportion of the electrons in each stage impinge upon their target.

The targets may be made of alkali metal on a suitable backing for example of silver oxide. In one example caesium is used and the secondary emission curve in this case is such that the ratio of secondary to primary emission increases from zero with increase of impact velocity from zero until a velocity of between 20 and 30 volts this ratio is unity. As the velocity is further increased, the ratio becomes greater than unity and at a velocity of about 200 volts reaches a value which is not greatly exceeded when the velocity is further increased. The ratio does not commence to fall until the velocity is of the order of 2000 to 5000 volts. The potential differences between electron sources and targets may therefore advantageously be made about 200 volts in this example. Thus with the cathode at zero volts the potentials of the targets $A_1$, $A_2$, $A_3$ and $A_4$ may be 200, 400, 600 and 800 volts respectively.

It is important that, at the surface of each target, there should be a field of sufficient strength to accelerate the secondary electrons liberated from this surface away from the surface as nearly normally thereto as possible. Clearly the primary electrons arriving at the surface have to pass through this field and the field tends to retard and deflect them. Hence this field must be kept small compared with the field which accelerates the primary electrons. It will be noted that in the device of Fig. 1 the primary electrons from the cathode 2 are accelerated to their maximum velocity at a considerable distance from the target $A_1$, because of the screen 4 which is at the same potential as the target $A_1$, and these primary electrons proceed from the point at which they attain their maximum velocity to the target by virtue of their momentum.

Although in the last paragraph reference has been made to primary and secondary electrons in the first stage, clearly the same arguments apply to the later stages. Thus the secondary electrons liberated at target $A_1$ can be regarded as the primary electrons for the second stage and so on.

It is, of course, not necessary that the acceleration in each stage should be effected by only one pair of cooperating electrodes. If desired one or more additional electrodes may be provided between the electron source and the target these electrodes being preferably maintained at potentials which increase progressively as their distance from the source increases so that the electrons are progressively accelerated to the required velocity. The grids G may if desired be separated from the screens, to which they are shown connected, and may be maintained at suitable different potentials from the screens. The electrodes may also be arranged to act, in known manner, as electron lenses so that they exert a concentrating effect upon the electrons. They may then be used to assist the coils M or the coils M may be omitted.

An example of the invention in which the concentrating effect is produced wholly electrostatically is shown in Fig. 2. In this figure and in Figure 1 like parts are given the same references.

In Figure 2 the envelope 14 is not of zig-zag shape but is in the form of a simple tube. In this case a photo-electric cathode 15 is used as the source of electrons. Light (represented by lines 16) falls upon the cathode 15 and liberates photo-electrons which are accelerated by an electrode 17 which is interposed between the cathode 15 and the screen 4. The electrons are concentrated and further accelerated by the field (indicated in dotted lines) between the electrode 17 and the screen 4 and strike the target $A_1$ to liberate secondary electrons therefrom. The electrodes 17 and 4 co-operate in forming an electron lens for the first stage and similar electron lenses

18 and 5, 19 and 6 and 20 and 7 are provided in the other stages. Grids G may be provided over the ends of electrodes 17, 18, 19, 20 and 3 as shown.

The potentials which may be applied to the various electrodes are indicated on the drawing. These potentials are negative potentials with respect to earth. It will be noted that in the present example the velocity of impact of the primary electrons upon the target in each stage is 500 volts.

The electrodes 17 and 4 act as electrostatic screens for screening the first stage from later stages. Corresponding electrodes in the other stages act in the same manner.

The device of Figure 2 as so far described provides a means of obtaining at 3 a very much larger electron current by the action of light than is possible with a simple photoelectric tube. If desired the device may be used as an amplifier of light variations, any variations in the light 16 being represented by relatively larger potential differences across the output impedance 12.

I claim:

1. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive said primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, concentric electrostatic and electromagnetic means for focusing the primary electrons upon the target electrode, and means for focusing the secondary electrons upon the second electrode.

2. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive said primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, and conductive means substantially completely surrounding the electron path between the source and the target electrode and between the target electrode and the second electrode for shielding the electron path from external electrostatic fields.

3. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive said primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, and conductive shielding means electrically connected to the target electrode and substantially completely surrounding the electron path between the source and the target electrode.

4. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, concentrating means including a first annular electrode intermediate the source of primary electrons and the target electrode for focusing the primary electrons upon the target electrode, and concentrating means including a second annular electrode intermediate the target electrode and the second electrode for focusing the secondary electrons upon the second electrode.

5. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive said primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, a first means for developing a magnetic field in the direction along the path of the electrons between the source and the target electrode, and a second means for developing a magnetic field in the direction along the path of the electrons between the target electrode and the second electrode, said first and second means being positioned at right angles to each other.

6. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive said primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, an electronic lens intermediate the source and the target electrode, and a second electronic lens intermediate the target electrode and the second electrode.

7. Apparatus comprising an evacuated envelope, a source of primary electrons, a secondary electron emissive target electrode positioned to receive said primary electrons, a second electrode positioned to receive secondary electrons liberated from the target electrode, a combined electromagnetic-electrostatic electron lens intermediate the source and the target electrode, and a second combined electromagnetic-electrostatic electron lens intermediate the target electrode and the second electrode.

8. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a first plurality of secondary electron emissive electrodes lying in a single plane, a second plurality of secondary electron emissive electrodes lying in a parallel plane, and in staggered relationship to the first plurality of electrodes, and axially symmetrical electron lenses positioned intermediate said first and said second plurality of electrodes.

9. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a first plurality of secondary electron emissive electrodes lying in a single plane, a second plurality of secondary electron emissive electrodes lying in a parallel plane, and in staggered relationship to the first plurality of electrodes, an output electrode, and axially symmetrical electron lenses positioned intermediate said first and said second plurality of electrodes.

10. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a first plurality of secondary electron emissive electrodes lying in a single plane, a second plurality of secondary electron emissive electrodes lying in a parallel plane, and in staggered relationship to the first plurality of electrodes, and combined axially symmetrical electrostatic-electromagnetic electron lenses positioned intermediate said first and said second plurality of electrodes.

11. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a first plurality of secondary electron emissive electrodes lying in a single plane, a second plurality of secondary electron emissive electrodes lying in a parallel plane, and in staggered relationship to the first plurality of electrodes, an output electrode, and combined axially symmetrical electrostatic-electromagnetic electron lenses positioned intermediate said first and said second plurality of electrodes.

12. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a first

plurality of secondary electron emissive electrodes lying in a single plane, a second plurality of secondary electron emissive electrodes lying in a parallel plane, and in staggered relationship to the first plurality of electrodes, and combined axially symmetrical electrostatic-electromagnetic electron lenses positioned intermediate said first and said second plurality of electrodes, and electromagnetic shielding means between each of the electromagnetic-electrostatic electron lenses.

13. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a first plurality of secondary electron emissive electrodes lying in a single plane, a second plurality of secondary electron emissive electrodes lying in a parallel plane, and in staggered relationship to the first plurality of electrodes, an output electrode, combined axially symmetrical electrostatic-electromagnetic electron lenses positioned intermediate said first and said second plurality of electrodes, and electromagnetic shielding means between each of the electromagnetic-electrostatic electron lenses.

14. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a secondary electron emissive electrode positioned to receive electrons from the electron gun, a control electrode and an electron lens intermediate the source and the secondary emissive electrode, a second secondary electron emissive electrode positioned to receive electrons from the first named secondary electron emissive electrode, focusing means intermediate the first and second secondary emissive electrodes for focusing the electrons upon the second secondary emissive electrode, a third secondary electron emissive electrode positioned to receive electrons from the second secondary emissive electrode, electron focusing means intermediate the second and third electrodes, a fourth secondary emissive electrode, and electron focusing means intermediate the third and fourth electrodes and an output electrode all of said focusing means being axially symmetrical.

15. Apparatus comprising an evacuated envelope, a source of electrons, means for focusing the electrons from the source into a beam, a secondary electron emissive electrode, positioned to receive electrons from the electron gun, a control electrode and an electron lens intermediate the source and the secondary emissive electrode, a second secondary electron emissive electrode positioned to receive electrons from the first named secondary electron emissive electrode, focusing means intermediate the first and second secondary emissive electrodes for focusing the electrons upon the second secondary emissive electrode, a third secondary electron emissive electrode positioned to receive electrons from the second secondary emissive electrode, electron focusing means intermediate the second and third electrodes, a fourth secondary emissive electrode, electron focusing means intermediate the third and fourth electrodes and an output electrode all of said focusing means being axially symmetrical, and electromagnetic shielding means intermediate each pair of successive focusing means.

16. An electric discharge device comprising an evacuated envelope, an electron source mounted within the envelope, an secondary electron emitter electrode mounted within the envelope and accessible to electrons from the source, a second secondary electron emitter electrode within the envelope accessible to secondary electrons from the first emitter electrode, an output electrode mounted within the envelope and being accessible to secondary electrons from the second emitter electrode means for establishing an axially symmetrical condensing electron lens intermediate the source and the first emitter electrode and means for establishing an axially symmetrical condensing electron lens between the first emitter electrode and the second emitter electrode.

17. An electric discharge device comprising an evacuated envelope, an electron-source, a secondary emitter-electrode and a target-electrode mounted in the order named within said envelope, said emitter-electrode being accessible to electrons from said source and said target-electrode being accessible to secondary-electrons from said emitter-electrode, and a plurality of apertured electrodes serially disposed between said emitter-electrode and said target-electrode for focusing said secondary-electrons upon said target-electrode, the apertures being substantially coaxial and substantially symmetrical with respect to a line drawn between said emitter and target electrodes.

18. An electric discharge device in accordance with claim 17 wherein said apertured electrodes are in the form of hollow cylinders.

19. An electric discharge device in accordance with claim 17 wherein two apertured electrodes are provided, said apertured electrodes being of substantially the same dimensions.

20. An electric discharge device in accordance with claim 17 wherein said target-electrode is mounted in a plane parallel to said emitter-electrode and offset therefrom.

21. An electric discharge device including an evacuated envelope, an electron source mounted within the envelope, a secondary electron emitter electrode within the envelope accessible to electrons from said source, a target electrode within the envelope accessible to secondary electrons from the emitter electrode, and an axially symmetrical concentrating electromagnetic electron lens intermediate the emitter electrode and the target electrode.

22. An electric discharge device including an evacuated envelope, an electron source mounted within the envelope, a secondary electron emitter electrode within the envelope accessible to electrons from said source, a target electrode within the envelope accessible to secondary electrons from the emitter electrode, and means whereby an electromagnetic field, symmetrical with respect to a line drawn between the emitter electrode and the target electrode may be established between said emitter and target for concentrating and focusing electrons upon the latter.

23. An electron multiplier comprising a source of electrons, an electron multiplying electrode capable of emitting secondary electrons, an output electrode, means for establishing an axially symmetrical electrostatic field between the source and the multiplying electrode, means for establishing an axially symmetrical electrostatic field between the multiplying electrode and the output electrode, means for establishing two axially symmetrical electromagnetic fields, each parallel respectively to the electrostatic fields, and means for shielding the electron source from the output electrode.

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