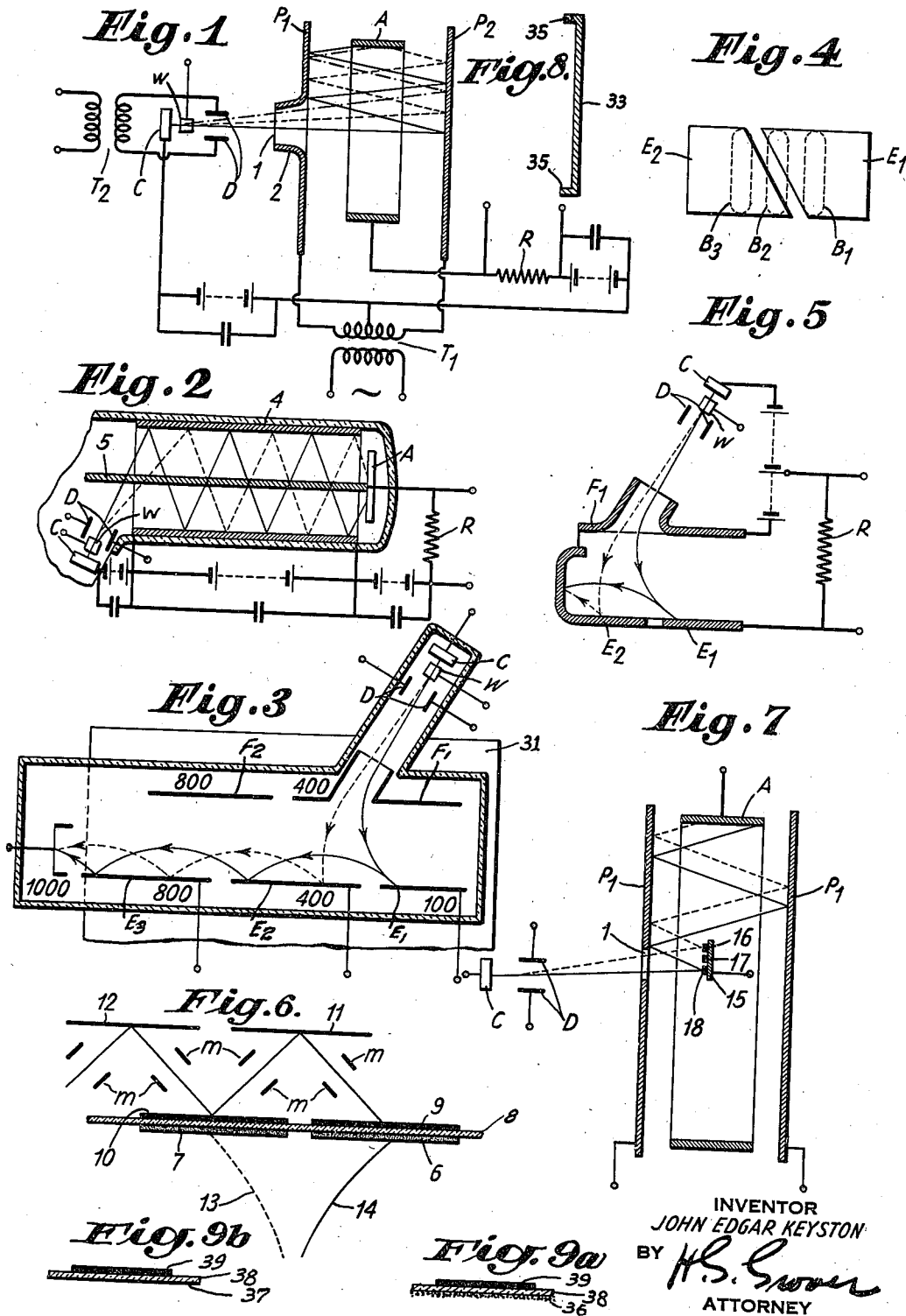


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ELECTRON MULTIPLIER

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ELECTRON MULTIPLIER

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The present invention relates to electron multipliers. An electron multiplier is a device in which a primary current I is amplified to a current $I, x_1, x_2 \dots x_n$ by causing the primary electrons constituting current I to strike a target and liberate therefrom Ix_1 secondary electrons, causing these secondary electrons to pass to an output electrode or to strike a second target and liberate therefrom Ix_1, x_2 tertiary electrons and so on, the factors $x_1, x_2 \dots x_n$ representing the ratio of secondary electrons liberated to primary electrons arriving at each stage up to the n th. The primary current I may be produced by photo-emission from an illuminated photo-cathode or by thermionic emission from a heated cathode or otherwise.

It has hitherto been proposed to control the intensity of the output current by controlling the intensity of the input current, for example by grid modulation or, in the case of photo-emission, by modulation of the light producing the photo-emission.

According to the present invention the output of an electron multiplier is varied with the aid of means for producing variation of the direction in which or the position from which the input electrons enter the multiplier.

One way in which this can be done is by causing the variation of direction or position to produce a variation in the number n of effective collisions which occur between the input and output of the multiplier, that is to say in the effective number of targets between the input and output of the multiplier. Another way is by causing variation of direction or position to produce a variation in one or more of the factors x_1, x_2 etc.

The present invention accordingly provides an electron multiplied arrangement having means for producing a variation in the effective number of targets between the input and the output of the multiplier.

The present invention also provides an electron multiplier arrangement having means operable with a fixed velocity of impact of primary electrons upon a target electrode for producing a variation in the number of secondary electrons emitted by the target electrode per primary electron striking it.

The invention will be described by way of example with reference to the accompanying diagrammatic drawing, in which Figs. 1, 2, 3, 5, 6 and 7 are views in elevation of the more important parts of six different forms of electron multiplier embodying the invention and Fig. 4 is a plan view of target electrodes which may be used

in the electron multiplier of Fig. 3. Like parts are given the same references in the different figures while Figs. 8, 9a and b show modifications of electrode structures shown in Figs. 1 and 6 respectively.

Referring to Fig. 1, there is shown what is known as an A. C. multiplier, that is to say a multiplier in which there are provided two target electrodes, represented by plates P_1 and P_2 to which an alternating potential difference is supplied by way of a transformer T_1 . Electrons from a source represented by C pass into the space between plates P_1 and P_2 through an aperture I in plate P_1 . The aperture I may be surrounded as shown by an approximately frusto-conical portion 2. A cylindrical output electrode A is arranged to surround the whole or part of the space between target electrodes P_1 and P_2 . The output electrode 23 may be provided with inwardly directed flanges 35 as shown in Fig. 8 to reduce the tendency of secondary electrons liberated by electrons reaching the output electrode to escape from the output electrode.

Suitable potentials are applied to the various electrodes as indicated and the output electrode is usually maintained more positive than the peak positive potential of the electrodes P_1 and P_2 . Suitable focusing means may if desired be provided in known manner to concentrate the beam of electrons from the cathode C and are shown in the figures as Wehnelt cylinder W as one example of such focusing means.

The frequency and amplitude of the oscillations applied at T_1 are so chosen that an electron passing through the aperture I when P_2 is positive and P_1 negative (or at its lowest positive value relatively to the source of primary electrons C), is accelerated towards P_2 and strikes P_2 just as the voltage of P_2 falls and that of P_1 rises so that the secondary electrons liberated at P_2 are drawn towards P_1 .

Deflecting means, represented by electrostatic deflecting plates D , are provided for deflecting the electron beam before it passes through the aperture I . In this way it can be arranged that with the undeflected beam secondary electrons liberated at P_2 are accelerated to P_1 to constitute primary electrons with respect to P_1 where they liberate secondary electrons which in turn are accelerated back to P_2 and so on along the path indicated by the full line in Fig. 1 to the output electrode A . In the particular example shown it will be seen that n is 4. When the electron beam is deflected it may follow the lower dotted track and n is then reduced to 3. If deflected to follow 5

the upper dotted track n is further reduced to 2.

It will be understood that in practice n may have a much higher value, for example 100, and the deflection of the beam may reduce n to say 90.

Electrical variations may be applied to control the deflection through transformer T_2 . The potential differences developed across output impedance R will then be in the form of high frequency oscillations of the frequency fed to T_1 modulated by the variations fed to T_2 .

It is to be understood that in this example and in other examples of the invention given later, deflection of the primary beam may be effected in any convenient manner. For example it is within the scope of the present invention in its broadest aspect to deflect the beam by mechanical movement of a suitable part of the apparatus.

In all cases, of course, the parts between which electron discharge is to take place are arranged within a suitable evacuated envelope.

An example of a D. C. multiplier according to the invention is shown in Fig. 2. In a D. C. multiplier the target electrodes are maintained at fixed potentials. In this case the target electrodes are constituted by a single tubular electrode 4 of resistive material. This may be formed as a thin coating upon the inner wall of a glass tube. A thin rod-shaped conductor 5 is arranged axially within the tube and a disc-shaped collecting or output electrode A is arranged at one end of the tube and is connected to the central conductor 5. The central conductor is maintained at a high positive potential, the end of the tubular electrode at which the collecting electrode is arranged is maintained at a positive potential lower than the central conductor and the other end of the tubular electrode is maintained at a still lower positive potential relatively to the source of electrons C arranged outside the tubular electrode. This source of electrons C is usually associated with means W for directing electrons in the form of a beam into the lower potential end of the tubular electrode in a direction making an acute angle with the central conductor 5. The electrons are accelerated by the central conductor but, on account of its small diameter few strike it and most pass on to strike the tubular electrode 4. The secondary electrons liberated at the surface of the tubular electrode are accelerated away from the surface by the central conductor. Most of the secondary electrons pass the central conductor and strike the inner wall of the tubular electrode at a point on the opposite side of the central conductor from the point at which they were liberated and because there is a potential gradient along the tubular electrode the point of impact of the secondary electrons is further from the input end than the point of liberation.

The path of the electrons is thus of zig-zag form and the electrons liberated by the last impact are collected upon the output electrode A.

Means, represented by plates D, are provided, as in the first example, for deflecting the primary electron beam and it can be arranged that the number of impacts n which take place, and hence the amplification, varies with the deflection. Thus when the electron track is that indicated by the full lines, n is equal to 6 and when the track is that represented by the dotted line, n is equal to 5.

Instead of an electrode having a potential gradient along it there may be used a series of

plates maintained at successively increasing potentials, proceeding from the source.

A somewhat different form of D. C. multiplier is shown in Fig. 3. Here the targets are constituted by three plates E_1 , E_2 and E_3 insulated from one another in a plane. These are maintained respectively at 100, 400 and 800 volts relative to the source of electrons. Above these target plates are arranged two other insulated plates F_1 and F_2 maintained at 400 and 800 volts. Some stagger is provided between the two sets of plates; thus the upper 800 volt plate lies partly above the 800 and partly above the 400 volt lower plate and the 400 volt upper plate lies partly over the 400 and partly over the 100 volt lower plate.

The upper group of plates is intended to give the electrostatic field the required form, more particularly a field normal to the surface of the target plates, this field serving to draw secondary electrons away from the targets. The upper plates do not act to any considerable extent as targets.

A beam of electrons is directed through an aperture in the plate F_1 towards the lower plates and means D are provided for changing the direction of the beam.

There is also provided in the neighborhood of the lower plates a magnetic field in a direction parallel to these plates and normal to the general directions of the electrons passing from one lower plate to the next, that is to say in a direction perpendicular to the plane of the paper in Fig. 3. The field may be produced by a permanent or an electro-magnet 31. This field is in such sense that, in combination with the normal electrostatic field, it causes secondary electrons liberated at the surface of one target plate to follow curved paths as indicated towards the next target plate at the higher potential. When the beam is undeflected it follows the full line track and strikes the plate E_1 and secondary electrons are drawn in a curved path from this plate to the next plate E_2 and so on so that n is 3. When the beam is deflected it first strikes the plate E_2 so that n is 2.

The output taken for example from the collector electrode A can be made to change gradually with deflection of the primary beam either by arranging that the incident beam is not sharply focused or by suitably shaping the first two target plates E_1 and E_2 . The shaping is indicated in Fig. 4 and is such that the adjacent edges lie at an acute angle to the beam of electrons (which may be of approximately rectangular cross-section as indicated by dotted lines) so that as the beam is deflected the ratio of the number of electrons striking one plate to the number striking the other changes gradually. Thus when the beam is undeflected it may fall at B_1 so that target E_1 is wholly operative. When partly deflected the beam may fall at B_2 so that E_1 is partly operative and when the beam is deflected to fall at B_3 the target E_1 is inoperative.

In order to arrange that the output current changes from a maximum value to zero with deflection of the beam, it may be arranged that as the deflection is increased beyond that indicated by the dotted line some of the electrons are caught by F_1 . A suitable diaphragm as disclosed by United States Patent No. 1,719,756, issued to Clay may be provided for example in the tubular part of F_1 for this purpose. As the deflection is increased more and more of the electrons are caught by F_1 until the whole of the electrons are arrested and the output is zero.

Another modification of the Fig. 3 arrangement having the same effect is indicated in Fig. 5. When the beam strikes the plate E₁, as shown in full lines, secondary electrons therefrom are collected by the plate E₂ and the output current has its maximum value represented by the difference between the secondary current and the primary current. When the beam is deflected as shown by the dotted lines so that it falls wholly on the collector electrode E₂ the output current is zero. By arranging that the undeflected direction of the beam is the one indicated by the dotted line, the output can be made to vary from zero to a maximum when the deflection is varied from zero upwards.

In all the arrangements so far described, the effect of deflection of the primary beam is to alter the effective number of targets between the input and output of the multiplier. In the arrangement of Fig. 6 a similar effect is produced by varying the position at which the primary beam effectively enters the multiplier.

In Figure 6 two fluorescent layers 6 and 7 are arranged upon one side of a transparent supporting sheet 8 and above these fluorescent layers are arranged photo-sensitive layers 9 and 10. Two target electrodes 11 and 12 are arranged, somewhat as indicated, above the layers 9 and 10. Assuming that the layer 9 is arranged at earth potential, the other elements are arranged at increasingly positive potentials in the order 11, 10, 12.

A beam of electrons is capable of being deflected to fall either along the full line track 14 to strike fluorescent layer 6 or along the dotted track 13 to strike fluorescent layer 7. In the former case the source of primary electrons for the multiplier is at the layer 9 because the light from the fluorescent layer 6 causes the photo-sensitive layer 9 to emit electrons. The electron path then includes targets 11, 10 and 12. When the electron beam falls along track 13 however, the targets 9 and 11 are inoperative and n is therefore reduced by 2. The electrons from target 12 may pass to an output electrode or to further stages of multiplication.

Suitable concentrating means indicated diagrammatically at m may be provided around the electron paths.

The fluorescent layers 6 and 7 and the photo-sensitive layers 9 and 10 need not be separate as shown but may be continuous, as shown in Fig. 9a, a suitable potential difference being maintained along the photo-sensitive layer 39 which is supported on the wall 38 and which has on the other side of the wall a layer of fluorescent material 36. The targets may then have the form shown in Fig. 2, that is to say a single resistive member may be used with a suitable potential gradient along it.

The arrangement of Fig. 6 can also be used without the fluorescent layers 6 and 7, as shown in Fig. 9b the electron beam 13, 14, being then replaced by a light beam which is deflected in order to vary the point at which the primary emission takes place. In Fig. 9b the photo-sensitive layer 39 is supported on the wall 38 and on the opposite side the reflector 37 is positioned.

The above examples of the invention are illustrative of cases where the effective number of collisions or targets n is changed. Where it is desired to vary the magnitude of one of the factors x_1 , x_2 etc. of the multiplier, one of the target electrodes, preferably the first, may be made with different secondary emitting properties at

different parts of its surface. When the ray is deflected it falls upon a part of different emissivity and the factor x_1 is thus varied.

In this example n remains constant although of course it may be arranged if desired that n is also varied, preferably in such sense as to be additive to the effect produced by the differently emitting surfaces 16, 17 and 18 of Fig. 7.

The auxiliary electrode 15 is held at a positive potential which is considerably lower than the peak potential of P₁ and thus may serve to reduce any tendency for secondary electrons to pass back through the aperture in P₁ towards the primary source C.

It will be seen that in the arrangement of Fig. 7 by deflecting the electron beam from C the number of secondary electrons emitted by the electrode 15 per primary electron striking it is varied. This effect is quite independent of any change in the velocity of impact of the primary electrons upon electrode 15, this velocity being determined by the potential difference between C and electrode 15, and the velocity of impact can therefore, as described, be kept constant.

The above described arrangements may be operated with increased sensitivity in the manner set forth in co-pending Application Serial No. 108,460, filed October 30, 1936, by Bull et al.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An electron multiplier comprising two target electrodes, connector means for applying an alternating potential different between said target electrodes, means for directing a beam of primary electrons into the space between said target electrodes, an output electrode adapted to collect secondary electrons liberated from said target electrodes and means intermediate the source and the initially impacted surface for varying the direction in which the beam of primary electrons strikes one of said target electrodes to control the effective secondary electron multiplication.

2. An electron multiplier comprising, two target electrodes, connector means for applying an alternating potential difference between said target electrodes, an auxiliary electrode adapted to act as a source of electrons for said target electrodes and having different secondary emitting properties at different parts of its surface, means for directing a beam of primary electrons at said auxiliary electrode to liberate electrons therefrom, an output electrode adapted to collect secondary electrons liberated from said target electrodes and means intermediate the source and the initially impacted surface for varying the direction in which the beam of primary electrons strikes said auxiliary electrode to control the effective secondary electron multiplication.

3. An electron device comprising, means to generate a concentrated beam of electrons, an electron multiplier having a plurality of stages, means for introducing the electron beam into the electron multiplier and means to vary the direction of initial beam introduction to vary the effective number of stages of the multiplier.

4. An electron device comprising, means to generate a beam of electrons, an input electrode, an output electrode, a plurality of secondary electron emissive electrodes intermediate the input and output electrodes, means to direct the generated beam of electrons upon the input electrode to eject secondary electrons, means to cause the ejected electrons to impact upon the intermediate electrodes, and means to vary the number of impacts.

5. An electron device comprising, means to generate a beam of electrons, an input electrode, a plurality of secondary electron emissive electrodes adjacent the input electrode, means to direct the generated beam of electrons upon the input electrode to eject secondary electrons, means to cause the ejected electrons to impact upon the secondary emissive electrodes, means to vary the number of impacts, and means including an output electrode for collecting the electrons from the last impaction.

6. The method of amplifying electrical energy which comprises the steps of producing a focused

beam of electrons, directing the produced beam of electrons upon an impact surface to release therefrom secondary electrons under the control of the impacting electrons, producing other secondary electrons in accordance with the initially produced secondary electrons, selectively controlling the direction along which the initially impacting electrons are directed to the impact surface to control the total number of secondary electrons released, and finally collecting the last produced secondary electrons.

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