

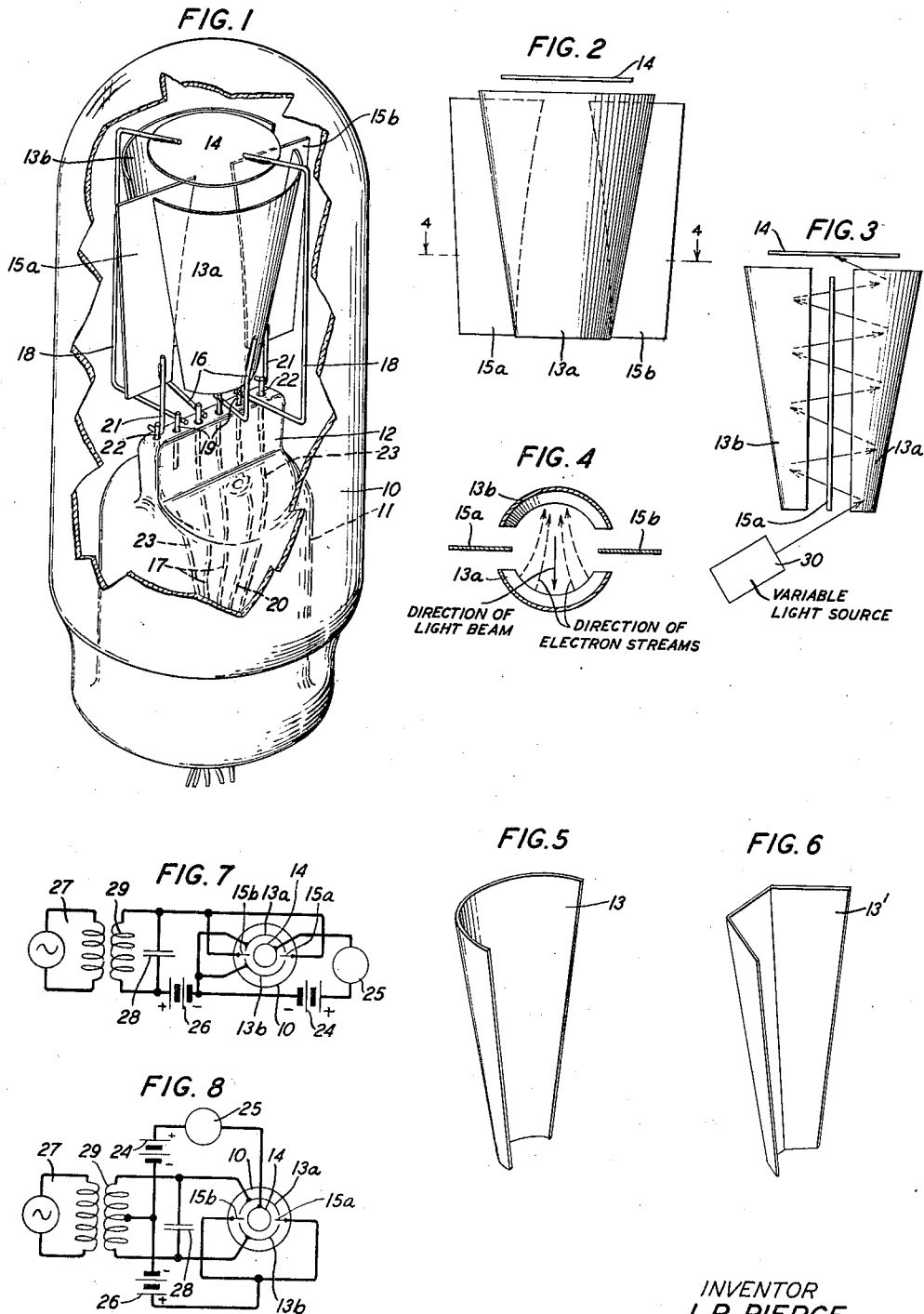
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ELECTRON DISCHARGE APPARATUS

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ELECTRON DISCHARGE APPARATUS

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This invention relates to electron discharge apparatus and more particularly to such apparatus including an electron discharge device having a pair of cooperating secondary electron emitting electrodes and commonly designated as electron multipliers.

One object of this invention is to facilitate the manifold amplification of electrical or light impulses.

Another object of this invention is to improve the efficiency and operating stability of high frequency electron multipliers.

Another object of this invention is to obtain substantially equal electron transit times for a multiplicity of electron streams flowing between a pair of electrodes in an electron multiplier.

Another object of this invention is to minimize or prevent space charge effects in electron multipliers.

A further object of this invention is to simplify the structure of electron multipliers.

Still another object of this invention is to increase the power capacity of electron multipliers.

In one illustrative embodiment of this invention, an electron multiplier comprises a pair of cathodes having opposed secondary electron emissive surfaces and a collector electrode or anode disposed adjacent one end of the cathodes. During operation of the multiplier, one of the surfaces is energized at the end thereof remote from the collector electrode or anode to cause emission of electrons therefrom. These electrons flow toward the opposite emissive surface and impinge thereon to cause the emission of secondary electrons therefrom. These secondary electrons, in turn, flow to the first surface and by impinging thereon cause the emission of other secondary electrons. This action is repeated along the two emissive surfaces, toward the collector electrode or anode, and the secondary electrons emanating from the end of one surface nearest the collector electrode flow thereto and constitute the output current.

Because of the character of the emissive surfaces, each impinging electron results in the release or emanation of a plurality of secondary electrons so that repeated electron multiplications of the original or primary electron current, and amplification of the signal or impulse corresponding thereto are obtained.

In accordance with one feature of this invention, the cathodes are so shaped that substantially all of the electrons emanating from each emissive surface are confined between these surfaces and are guided or focussed so that they

impinge upon the opposite surface. In one illustrative form, the cathodes may be opposed halves of frustrums of cones or pyramids, the larger ends thereof being toward the collector electrode or anode.

In accordance with another feature of this invention, means are provided for producing strong fields between the emissive surfaces so that the electrons emanating from each surface are subjected to accelerating fields and caused to impinge at high velocities upon the other surface. This means enables the attainment of very low and uniform transit times and voltage saturation of the electrons. In one illustrative form, the accelerating electrodes may be diametrically opposite plate members extending between adjacent longitudinal edges of the cathodes.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a perspective view of an electron multiplier illustrative of one embodiment of this invention, portions of the enclosing vessel being broken away to show details more clearly;

Figs. 2 and 3 are side views in elevation and at positions at right angles to each other of the electrodes of the electron multiplier shown in Fig. 1, illustrating the form and space relation thereof;

Fig. 4 is a view in section along line 4—4 of Fig. 2;

Fig. 5 is a detail perspective view of one of the cathodes embodied in the multiplier shown in Fig. 1;

Fig. 6 is another perspective view illustrating a modification of the cathode shown in Fig. 5; and

Figs. 7 and 8 are circuit diagrams illustrating typical ways in which an electron multiplier constructed in accordance with this invention may be operated.

Referring now to the drawing, the electron multiplier shown in Fig. 1 comprises a highly evacuated enclosing vessel 10 having an inwardly extending stem 11 at one end, terminating in a press 12. Mounted above the stem are a pair of cathodes 13a and 13b, an anode or collector electrode 14 and a pair of auxiliary, accelerating or field electrodes 15a and 15b.

The cathodes 13 may be formed of sheet metal, for example sheet silver, and the opposed surfaces thereof are treated or coated to form a coating or layer having good secondary electron emitting properties. For example, these sur-

faces may be treated to form thereon a matrix including silver, caesium oxide and some free caesium. These surfaces, furthermore, are elongated and channel shaped, increasing in width and spacing toward the collector electrode or anode 14. For example, as shown clearly in Figs. 3 and 5, each of the cathodes may be substantially one-half of a right frustum of a cone, the larger base being toward the collector electrode or anode. Preferably, as shown in Fig. 4, the cathodes 13 are concentric with each other.

The cathodes 13 may be mounted individually by rigid metallic supports or uprights 16 affixed to and extending from leading-in conductors 17, which are embedded in the press 12 and project through the stem 11.

The anode or collector electrode 14 may be a metallic plate or disc, preferably coaxial with the axis of concentricity of the cathodes 13, supported by a pair of rigid metallic uprights or supports 18 arising from wires 19 sealed in the press 12. Electrical connection to the collector electrode or anode may be established through a leading-in conductor 20 connected to one of the wires 19.

The auxiliary electrodes 15a and 15b may be metallic coplanar plates, extending diametrically opposite with respect to the cathodes 13 and between the juxtaposed longitudinal edges thereof. These electrodes 15a and 15b may be supported by rigid rods or wires 21 extending from metallic stubs 22, which are embedded in the press 12 and have leading-in conductors 23 connected thereto. Preferably, as illustrated in Fig. 2, the inner edges of the auxiliary electrodes are somewhat curved and equally spaced on opposite sides of the axis of concentricity of the cathodes 13.

During operation of the electron multiplier, as illustrated in Figs. 7 and 8, the anode or collector electrode 14 may be maintained at a positive potential, for example of the order of 200 volts, with respect to the two cathodes 13, as by a source 24, such as a battery, in series with an output device or circuit 25, and the auxiliary electrodes 15a and 15b likewise may be maintained at a positive potential, for example, of the order of 200 volts, with respect to the cathodes 13, as by a source 26, such as a battery. Means are provided for producing a high frequency field between the opposed or concave surfaces of the cathodes 13.

As illustrated in Fig. 7, this high frequency field may be obtained through an oscillator 27 coupled between the cathodes 13 tied together and the auxiliary electrodes tied together through an anti-resonant circuit including a condenser 28 and inductance 29 connected in parallel.

Alternatively, as illustrated in Fig. 8, the oscillator 27 may be coupled to the anti-resonant circuit 28, 29 connected directly between the cathodes 13a and 13b.

Preferably, the frequency of the oscillator is such that in the arrangement shown in Fig. 7,

$$f = \frac{1}{T}$$

and in the arrangement shown in Fig. 8,

$$f = \frac{1}{2T}$$

where f is the frequency and T is the electron transit time between the two cathodes 13a and 13b.

When a portion of the dished or concave surface at one end of one of the cathodes, for example, the lower end of the cathode 13a in Fig. 3, is energized, as by a beam of light focussed thereon from a variable light source 30, primary or photoelectrons are emitted. These electrons come under the influence of two fields, namely, a strong field produced by the auxiliary electrodes 15a and 15b, which accelerates the electrons away from the cathode 13a and toward the dished or concave surface of the cathode 13b, and a high frequency field accelerating the electrons in the direction of the collector electrode or anode 14. The primary or photoelectrons will traverse paths as indicated generally by the arrows in Fig. 4 and impinge upon a portion of the concave surface of the cathode 13b spaced from the end thereof remote from the anode or collector electrode 14. The impinging electrons will cause the emanation of secondary electrons from this portion of the cathode 13b, the secondary electron current being several times as great as the primary electron current because of the treatment or coating of the concave surfaces of the cathodes as heretofore described. These secondary electrons under the influence of the high frequency field and the accelerating field created by the auxiliary electrodes 15 flow to the cathode 13a, impinge thereon at an area displaced toward the collector electrode with respect to the area of emanation of the primary electrons, and thereby cause the emission of a still greater secondary electron current from the cathode 13a. This action is repeated along the cathodes 13a and 13b, toward the anode or collector electrode, the electron trajectories being indicated generally by the arrows in Fig. 3, and the electrons emanating at the end adjacent the anode or collector electrode flow thereto and constitute the output current. Because of the repeated electron multiplications at the cathodes, the output current will be much greater than the primary electron current and hence represents a manifold amplification of the signal corresponding to the light beam produced at the source 30.

Because of the inclination of the emissive surfaces of the cathode and the direction of the fields thereadjacent, the electrons emanating from each portion of these surfaces will be directed toward a portion of the opposite surface nearer the collector electrode or anode. Inasmuch as these surfaces are channel shaped, concave or dished, the various electron streams will be substantially confined between these surfaces and the streams originating at each surface will be focussed upon a restricted portion or area of the opposite surface. Hence, concentration of the electron streams is achieved and the attainment of a high efficiency enabled.

The auxiliary electrodes, as noted heretofore, provide strong fields accelerating the electrons emanating from each of the electron emissive surfaces and thereby insure relatively short electron transit times and, in addition, assist in the focussing of the electron streams. Furthermore, the strong fields assure acceleration of substantially all electrons away from the surface at which they originate, prevent space charge effects and allow voltage saturation of the electron streams.

The effect of the increase in spacing between the emissive surfaces of the cathodes, toward the collector electrode or anode, is counteracted by the increased extent to which the auxiliary electrodes extend between the two cathodes so that

substantially equal electron transit times are obtained along all the paths followed by the electrons flowing between the two cathodes.

As will be noted, particularly from Fig. 2, the extent to which the auxiliary electrodes 15a and 15b project between the two cathodes 13 increases toward the collector electrode or anode so that consequently the fields increase in intensity in the same direction in which the space current increases, that is, toward the collector electrode. Hence, space charge effects in the vicinity of the collector electrode or anode are substantially minimized and undue restriction of the output current of the multiplier is prevented.

The fields may be varied or adjusted as desired by altering the distance between the opposed edges of the auxiliary electrodes, by altering the distance to which these electrodes project toward the axis of the electrode structure or by altering both of these distances.

It may be remarked that in electron multipliers constructed in accordance with this invention, the various electron streams are concentrated solely by the fields produced by and between the electrodes so that the use of external means, such as magnets or field coils, is obviated, and, thereby, the construction of electron multiplying apparatus is greatly simplified and its cost reduced.

It may be remarked also that in electron multipliers constructed in accordance with this invention, because of the configuration and space relation of the emissive surfaces, the electrons emanating from any small area in one surface are prevented from returning to the same area so that the establishment of a space charge condition or electron regeneration effect is precluded. Hence, a large increase in output current substantially independently of an increase in the original or primary current occasioned by the light beam is avoided and stable operation of the multiplier is attained.

Although specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative of this invention. For example, although the cathodes 13 have been shown and described as semi-frustro-cones, they may be of other configuration, such as semi-frustro-pyramids as illustrated in Fig. 6. Also, although the cathodes have been shown as having linear longitudinal elements and constant lateral curvature, they may be curved somewhat longitudinally, and the curvature of successive or spaced lateral sections may be changed to improve or alter the degree of convergence and focussing of the various electron streams. Various other modifications may be made in the structures and circuits disclosed without departing from the scope and spirit of this invention as defined in the appended claims.

Reference is made of the application Serial No. 227,649, filed August 31, 1938, of William Shockley, disclosing a related invention.

What is claimed is:

1. An electron multiplier comprising a pair of opposed channel-shaped cathodes, and a collector electrode at one end of said cathodes, the spacing between the opposed surfaces of said cathodes increasing toward said collector electrode.
2. An electron multiplier comprising a pair of cathodes having elongated opposed electron emissive surfaces and longitudinal edges, a collector electrode at one end of said surfaces, and auxiliary electrodes adjacent the longitudinal edges of said cathodes and substantially coextensive therewith.
3. An electron multiplier comprising a pair of opposed electron emissive surfaces having juxtaposed longitudinal edges, the spacing between said surfaces increasing toward one end thereof, a collector electrode adjacent said end, and a field electrode extending between juxtaposed longitudinal edges of said surfaces.
4. An electron multiplier in accordance with claim 3 wherein the distance to which said field electrode extends inwardly from said edges increases toward said one end of said surfaces.
5. An electron multiplier comprising a pair of cathodes having opposed elongated concave emissive surfaces increasing in lateral section from one end to the other and having juxtaposed longitudinal edges, and a collector electrode adjacent one end of said surfaces.
6. An electron multiplier in accordance with claim 5 comprising a pair of auxiliary electrodes adjacent the longitudinal edges of said surfaces.
7. An electron multiplier comprising a pair of elongated concentric, concave emissive surfaces, a collector electrode at one end of said surfaces, and substantially coplanar plate electrodes extending between adjacent edges of said surfaces and substantially coextensive therewith.
8. An electron multiplier comprising a pair of electrically separate, substantially semi-conical electron emissive surfaces facing each other and having opposed, spaced longitudinal edges, and a collector electrode opposite the base of said surfaces.
9. An electron multiplier in accordance with claim 8 comprising a pair of plate auxiliary electrodes extending between the opposed longitudinal edges of said surfaces.
10. An electron multiplier comprising a pair of cathodes having opposed, concentric, substantially semi-conical electron emissive surfaces and juxtaposed longitudinal edges, a pair of diametrically opposite coplanar plate electrodes extending between said edges, and a collector electrode opposite the base of said surfaces.
11. An electron multiplier in accordance with claim 10 wherein the inner edges of said plate electrodes are curved and equally spaced on opposite sides of the axis of concentricity of said surfaces.

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