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J. R. PIERCE

2,207,354

ELECTRON DISCHARGE APPARATUS

Filed May 4, 1938

FIG. 1

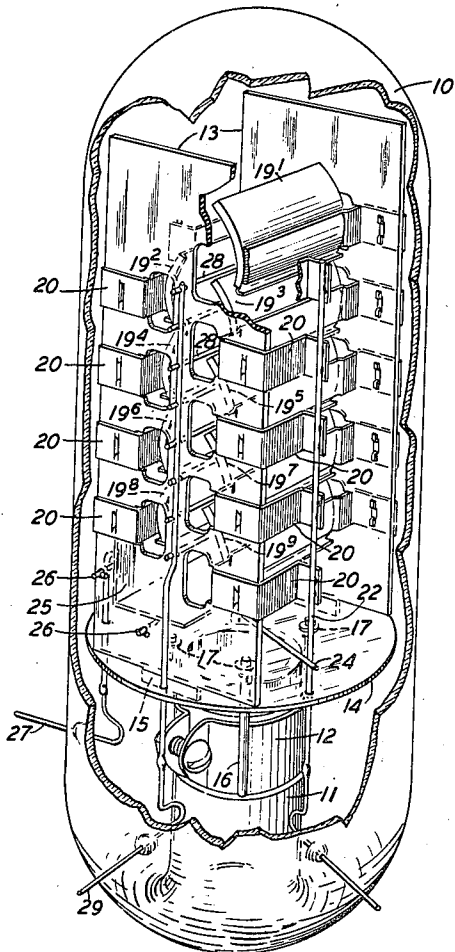


FIG. 2

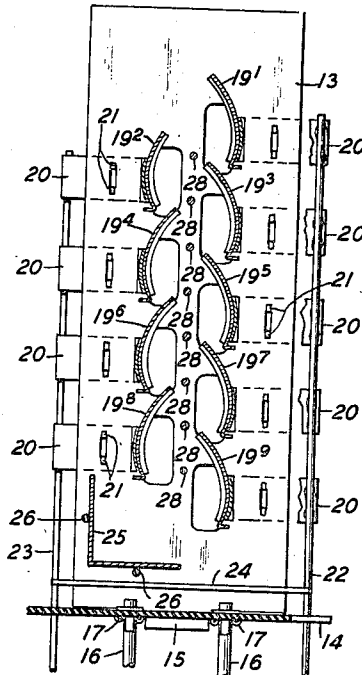
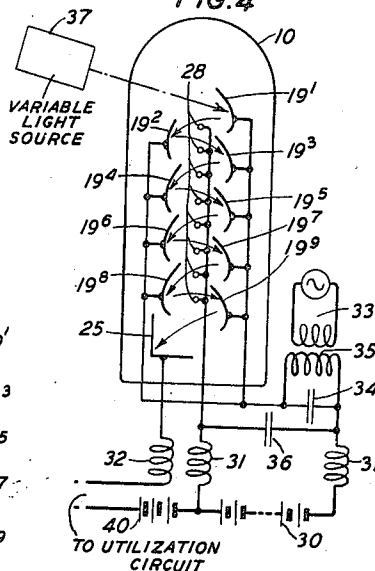


FIG. 4



UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE APPARATUS

John R. Pierce, New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application May 4, 1938, Serial No. 205,927

10 Claims. (Cl. 250—27)

This invention relates to electron discharge apparatus and more particularly to such apparatus including electron discharge devices, such as disclosed in the applications Serial No. 205,930, filed May 4, 1938, of John R. Pierce; Serial No. 176,566, filed November 26, 1937, of John R. Pierce and William Shockley; and Serial No. 205,931, filed May 4, 1938, of Gordon K. Teal, having secondary electron emitting electrodes and commonly designated as electron multipliers.

One object of this invention is to enable the manifold amplification of relatively weak impulses.

Another object of this invention is to obtain a high degree of convergence of the several electron streams in high frequency electron multipliers.

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

A further object of this invention is to increase the efficiency and to improve the operating characteristics of electron multipliers operable at high frequency potentials.

In one illustrative embodiment of this invention, an electron multiplier comprises a pair of cathodes having opposed rows of electron emissive members mounted in staggered relation. Each row may include a plurality of such members electrically connected together. The first or one end member in one of the rows may have a photoelectric surface and serve as a primary cathode or primary electron source and the other members may have corresponding surfaces thereof coated with a material having good secondary electron emitting characteristics and serve as secondary cathodes. A collector electrode is mounted adjacent the end of the rows remote from the primary cathode.

An auxiliary electrode, for example, a reticulated member or grid, is mounted between the rows of electron emissive members and serves to provide strong fields drawing the electrons away from each of the emissive members and accelerating them toward the next succeeding member whereby low and uniform electron transit times and voltage saturated electron currents between successive members are obtained. The auxiliary electrode, in addition, assists in focussing the electrons emanating from each emissive member, upon the next succeeding member or upon the collector electrode or anode.

During operation of the electron multiplier, all of the electron emissive members may be connected together electrically and maintained at a negative potential with respect to the aux-

iliary electrode and the collector electrode, the latter preferably being operated at a potential somewhat more positive than the auxiliary electrode. A high frequency potential is applied between the auxiliary electrode and the emissive members.

The invention and the various 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 and of the electrode assembly being broken away to show details more clearly;

Fig. 2 is a side view partly in section, of the electrode structure included in the electron multiplier shown in Fig. 1;

Fig. 3 illustrates a modification of the cathode structures incorporated in the embodiment shown in Figs. 1 and 2; and

Figs. 4 and 5 are diagrams, partly schematic, illustrating amplifiers including an electron multiplier of the construction shown in Figs. 1 and 2.

Referring now to the drawing, the electron multiplier shown in Figs. 1 and 2 comprises an evacuated enclosing vessel 10 having an inwardly extending stem 11 at one end, the stem having clamped thereabout a split metallic collar or band 12 from which a unitary electrode assembly is supported. This assembly includes an insulating frame comprising a pair of uprights 13, for example strips of mica, and a disc 14, also, for example, of mica, the uprights 13 having integral projections or tongues 15 closely fitted in parallel slots in the disc 14. The insulating frame may be supported by a plurality (four) of rigid metallic rods or wires 16 extending from the band or collar 12, the rods or wires 16 extending through the disc 14 and being securely affixed thereto as by eyelets 17.

Supported between the insulating uprights 13 are two parallel rows of substantially identical electrode elements 19¹ to 19ⁿ, inclusive, arranged in staggered relation. The electrode elements in each row may be curved, have their concave surfaces toward the elements in the other row, and equally spaced. The electrode elements 19 may be, for example, strips of metal and the opposed or concave surfaces thereof may be coated or treated so that the inner or concave surface of the element 19¹ is photoelectrically active and the inner or concave surfaces of the elements 19² to 19ⁿ, inclusive, have good secondary electron emitting characteristics. In a specific form, the

elements 19 may be strips of silver and the inner surfaces thereof may be treated to form a matrix or coating including caesium oxide, silver and free caesium.

Each of the electrode elements 19 is supported by a bracket member 20, for example, a strip of nickel, extending between the uprights 13 and having arms bent around the uprights and locked thereto as by integral tabs 21. The elements 19 having odd superscripts may be connected electrically to one another by a leading-in conductor 22 and the elements 19 having even superscripts may be connected similarly by a leading-in conductor 23. If desired, the two conductors 22 and 23 may be connected electrically, as by a tie wire 24 so that all of the electrode elements 19 may be operated at the same direct current potential.

Mounted adjacent one end of the rows of electrode elements 19 is a collector electrode or anode 25, which may be an L-shaped metallic plate supported by rods or wires 26 extending between the insulating uprights 13 and fitted in apertures therein. Electrical connection to the collector electrode or anode may be established through a leading-in conductor 27.

Disposed in the medial plane between the two rows of electrode elements 19 is a reticulated auxiliary or accelerating electrode which may comprise a plurality of parallel small area rods or wires 28 extending between the uprights 13 and fitted in apertures therein. As shown clearly in Fig. 2, each of the rods or wires 28 is opposite and parallel to the concave surface of a corresponding electrode element 19 and generally centrally located with respect thereto, and is adjacent and parallel to the upper edge of the next succeeding electrode element. Leading-in connection to the auxiliary or accelerating electrode may be established through a conductor 29. The wires or rods 28 may be treated suitably to substantially prevent the emission of secondary electrons therefrom.

In order to reduce end effects, portions of the uprights 13 adjacent the sides of the electrode elements 19 may be cut away as shown in Figs. 1 and 2.

During operation of the electron multiplier, as shown in Fig. 4, the auxiliary or accelerating electrode composed of the wires 28 is maintained highly positive, for example of the order of 200 volts, with respect to the electrode elements 19, as by a source, such as a battery 30, in series with high frequency choke coils 31. A high frequency potential is impressed between the accelerating or auxiliary electrode 28 and the electrode elements 19 by an oscillator 33 through a resonant circuit including a condenser 34 and inductance 35, a blocking condenser 36 being connected as shown. The frequency of this potential preferably should be such that

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

where f is the frequency and T is the transit time of an electron flowing from one of the elements 19 to the next succeeding one.

The collector electrode or anode 25 is maintained at a positive potential, somewhat higher than that of the auxiliary electrode 28, for example of the order of 300 volts with respect to the electrode elements 19, by a source 40, a high frequency choke coil 32 being in circuit as shown. An output or utilization device or circuit may be connected between the source 30 and the collector electrode or anode as indicated.

In an alternative arrangement illustrated in Fig. 5, the resonant circuit 34, 35 is connected between the two cathodes so that the high frequency potential is impressed between these two electrodes. In this case, the frequency of the oscillator preferably should be one-half the electron transit time between the two cathodes.

When the electrode element 19¹ is energized, as by a beam of light focussed thereon from a variable light source 37, the photoelectrons emitted therefrom are accelerated away from the emitting surface, due to the high positive potential upon the auxiliary electrode 28, and flow to the electrode element 19², the electrons being accelerated in the direction of the longitudinal axis of the tube by the high frequency field produced by the oscillator 33. These electrons, impinging upon the element 19², cause the emission of secondary electrons from the latter. The secondary stream will be greater than the impinging stream because of the treatment or coating of the inner or concave surface of the element 19² so that, in effect, an electron multiplication or amplification occurs. The secondary electrons emanating from the electrode element 19² are accelerated in the direction toward the collector electrode by the high frequency field, accelerated away from the element 19² by the field resulting from the potential upon the auxiliary electrode 28, and impinge upon the electrode element 19³ to cause the emission of a greater number of electrons therefrom and, hence, to result in a further electron multiplication or amplification. This phenomenon is repeated at each of the succeeding electrode elements 19⁴ to 19ⁿ and those electrons ultimately emanating from the electrode element 19ⁿ flow to the anode or collector electrode 25 and constitute the output current of the multiplier. The electron paths are indicated generally by the arrows in Fig. 4.

Because of the curvature of the electrode elements 19, the electron streams emanating from each element will be converged and focussed upon the next succeeding element, or upon the anode or collector electrode, so that a high efficiency and stable operation result. This convergence and focussing is augmented by the rods or wires 28 of the auxiliary electrode.

The high potential upon the auxiliary electrode causes great acceleration of the electrons flowing between successive elements so that very short and uniform electron transit times obtain. In addition, this potential assures flow of substantially all the electrons emitted from each element, away from the element, so that voltage saturation and large currents may be achieved.

The electrode elements, it will be appreciated, may be of relatively large area so that large output currents may be achieved without deleterious heating of the electrodes.

As shown in Fig. 3, the electrode members 19 in each of the rows may be fabricated as a unit from metallic strips or sheets 38, the elements 19 being cut and formed directly from the sheets.

Although specific embodiments of this invention have been shown and described it will be understood, of course, that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a pair of electrodes having opposed electron emissive surfaces, a collector electrode at one end of said electrodes, a reticulated electrode between

said surfaces, an output circuit connected between said collector electrode and said pair of electrodes, means maintaining said reticulated electrode at a positive potential with respect to said pair of electrodes, and means for impressing a high frequency potential between said reticulated electrode and said pair of electrodes.

2. Electron discharge apparatus comprising a primary electron source, a collector electrode, a pair of secondary cathodes between said collector electrode and said source and having opposed emissive surfaces, an auxiliary electrode between said emissive surfaces, means electrically connecting said secondary cathodes, an output circuit connected to said collector electrode and said cathodes, means maintaining said auxiliary electrode at a positive potential with respect to said cathodes, and means for impressing a high frequency potential between said auxiliary electrode and said cathodes.

3. Electron discharge apparatus comprising a pair of cathodes having opposed emissive surfaces, means connecting said cathodes together so that said cathodes are at the same direct current potential, means for energizing one of said surfaces adjacent one end thereof, a collector electrode at the other end of said surfaces, an output circuit connected between said cathodes and said collector electrode, means separate from said cathodes for producing an electron accelerating potential between said surfaces and away therefrom, and means for producing a high frequency field between said surfaces.

4. Electron discharge apparatus comprising a pair of cathodes each including a plurality of spaced concave emissive surfaces, the emissive surfaces of one cathode being opposite and in staggered relation with those of the other cathode, a collector electrode at one end of said cathodes, means for energizing the other end of one of said cathodes to cause electron emission therefrom, an output circuit connected between said cathodes and said collector electrode, means for producing a substantially constant potential accelerating field between said cathodes and away from said emissive surfaces, and means for producing a high frequency field in the space between said cathodes and directed from said one end toward said collector electrode.

5. Electron discharge apparatus comprising a pair of cathodes each including a plurality of similar spaced elements having concave electron emissive surfaces, the elements of one cathode being in staggered relation with those of the other cathode and the emissive surfaces thereof facing those of the other cathode, an auxiliary electrode between said cathodes including a plurality of elements each of which is opposite a corresponding one of said surfaces, means for energizing one of said cathodes at one end thereof to cause electron emission, a collector electrode at the other end of said cathodes, an output circuit connected between said cathodes and said collector electrode, means maintaining said auxiliary electrode

at a positive potential with respect to said cathodes, and means for impressing a high frequency potential between said auxiliary electrode and said cathodes.

6. Electron discharge apparatus comprising an elongated auxiliary electrode, a cathode on one side of said auxiliary electrode including a plurality of dished electron emissive surfaces facing said auxiliary electrode, a second cathode on the other side of said auxiliary electrode including a plurality of dished electron emissive surfaces facing said first surfaces, means for energizing the emissive surface at one end of one of said cathodes to cause emission therefrom, a collector electrode at the opposite end of one of said cathodes, means electrically connecting said cathodes together, an output circuit connected between said cathodes and said collector electrode, means maintaining said collector electrode and auxiliary electrode at positive potentials with respect to said cathodes, and means impressing a high frequency potential between said cathodes and said auxiliary electrode.

7. An electron multiplier comprising a pair of cathodes having opposed electron emissive surfaces, means for energizing one of said cathodes to cause electron emission from adjacent one end thereof, a collector electrode opposite the other end of said cathodes, an output circuit connected to said collector electrode, means including a reticulated auxiliary electrode mounted in substantially the medial plane between said surfaces for producing an accelerating field away from said surfaces, and means for producing a high frequency field in the region between said surfaces.

8. An electron multiplier in accordance with claim 7 wherein said cathodes are connected together, and said last means includes a resonant circuit connected between said cathodes and said auxiliary electrode, and an oscillator coupled to said circuit.

9. An electron multiplier in accordance with claim 7 wherein said last means includes a resonant circuit connected between said cathodes, and an oscillator coupled to said circuit.

10. Electron discharge apparatus comprising a plurality of electrode elements mounted in two rows and in staggered relation, opposed surfaces of said elements being electron emissive, means for energizing one of said elements at one end of one of said rows to cause electron emission therefrom, a collector electrode adjacent the opposite end of said rows, an output circuit connected to said elements and to said collector electrode, an auxiliary electrode electrically separate from said collector electrode, mounted between said rows and having portions opposite each of said surfaces, means maintaining said auxiliary electrode at a positive potential with respect to said elements, and means for producing a high frequency field in the vicinity of said surfaces.

JOHN R. PIERCE.