Aug. 11, 1942. J. A. RAJCHMAN 2,292,847

ELECTRON MULTIPLIER

Filed Nov. 30, 1939

FIG. 1.

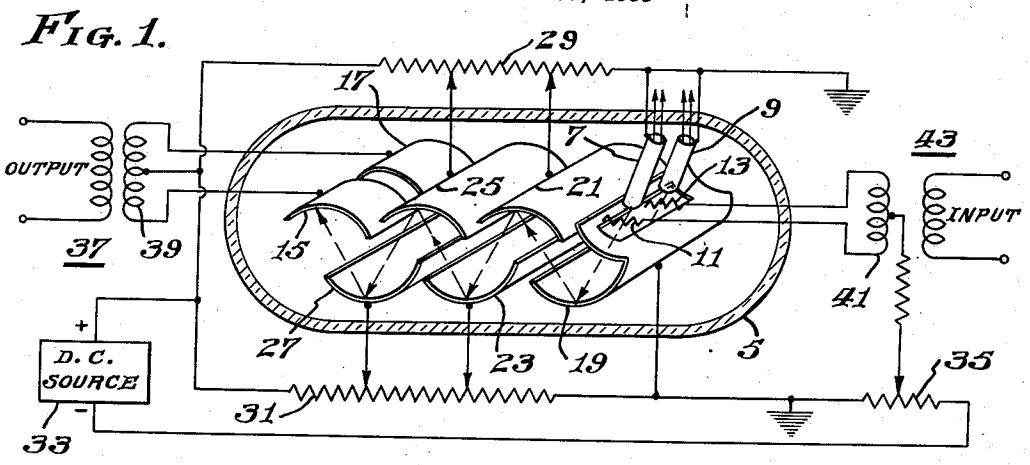


FIG. 2.

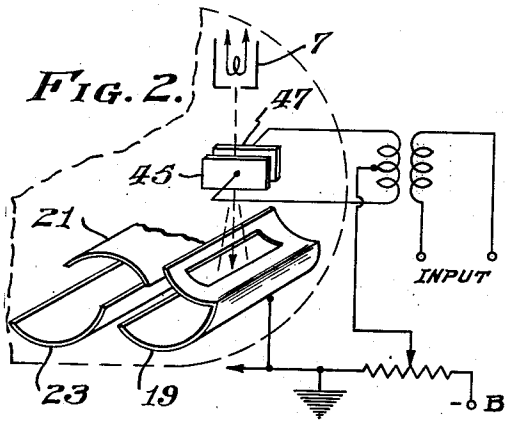


FIG. 3.

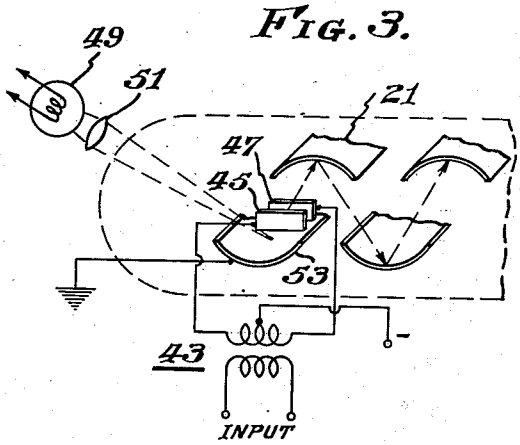
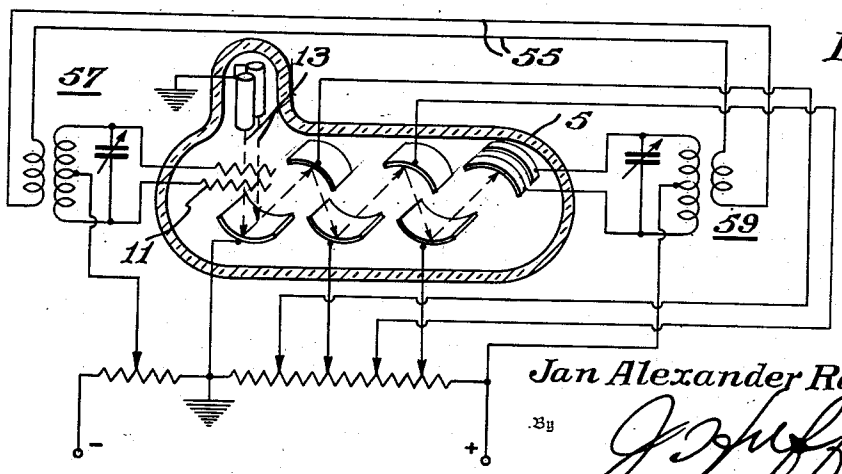


FIG. 4.



Inventor

Jan Alexander Rajchman

By

Attorney

Patented Aug. 11, 1942

2,292,847

UNITED STATES PATENT OFFICE

2,292,847

ELECTRON MULTIPLIER

Jan A. Rajchman, Philadelphia, Pa., assignor to Radio Corporation of America, a corporation of Delaware

Application November 30, 1939, Serial No. 306,836

5 Claims. (Cl. 179—171)

This invention relates to electron multipliers, and particularly to an electron multiplier for use as an ultra high frequency oscillator detector or amplifier.

I am aware of electron multipliers of the type wherein amplification of a primary electron stream, such, for example, as is emitted from a thermionic cathode or from a photosensitive surface exposed to light, is accomplished through utilization of the phenomenon of secondary emission. Such a device is described and claimed in United States Patent No. 2,073,599 of L. Malter, for "Electric discharge devices."

Electron multipliers of the type described in the above-identified patent have most frequently been used to amplify currents which fluctuate at audio or low radio frequencies. For example, the photoelectric multiplier has been successfully used in the electrical reproduction of light variations produced by the sound track of a moving picture film. Tremendous amplification can be obtained in this manner. However, electron multipliers have not been as successfully operated at high radio frequencies, and particularly at ultra high frequencies, since the known tubes have certain characteristics which make their operation at high frequencies not altogether satisfactory.

To understand why electron multiplier tubes have proved unsatisfactory for high frequency work, the operation of a secondary emissive electrode when impinged by a beam of high velocity electrons may be considered. In accordance with the theory of secondary emission, each impinging electron releases a number of secondary electrons which are drawn away from the electrode by the electrostatic field produced by adjacent electrodes. This means that there is a net loss of electrons, which is the equivalent of an electric current flowing from the electrode through the connecting lead to the source of direct current energizing potential. As long as the current amplitude remains constant, the potential of the electrode will remain constant likewise. The actual electrode potential will, of course, be determined by the potential of the direct current power source plus or minus the voltage drop in the conductor, depending upon the direction of current flow. When the current is constant, the impedance of the conductor is determined solely by its D. C. resistance, which is negligible.

However, when the intensity of the impinging electron beam is varied by a modulating voltage, the current flowing to or from each secondary emissive electrode varies likewise. An alternating voltage drop is produced in the lead to the electrode which is a function of the reactance of the conductor, and the reactance in turn is a function of the frequency. At high frequencies, the potential of the electrode is no longer constant, but varies through such a wide range that the normal operation of the multiplier is rendered unsatisfactory.

One undesirable effect of the variation of electrode potential that has been noticed is the inherent tendency of the multiplier to oscillate. This effect is explained as follows: There is a capacitive coupling between the control grid and the nearest secondary emissive electrode. If for any reason the grid becomes more positive, the intensity of the stream of primary electrons increases. This causes a greater increase in the secondary electron emission so that there is an increased loss of electrons. Due to the greater loss of electrons, the potential of the electrode in question becomes more positive. This change of potential is then coupled back to the control grid and causes a still further increase in the intensity of the stream of primary electrons. When the point of saturation is reached, the process is reversed, and oscillation has begun. Similarly, the same effect is noticed when the tube is used as an amplifier. Even if the feed back is not sufficient to produce oscillation, the variation of the potentials of the multiplying electrodes disturbs the focusing of the electrons, and prevents any effective gain from being realized.

It is the primary object of this invention to overcome the disadvantages noted above and to provide an electron multiplier which has a very high mutual conductance (per unit of anode current), and which can be used at ultra high frequencies. Briefly, this object is accomplished by providing means for modulating the electron stream without causing a change in the total current flowing to any of the secondary emissive electrodes. If the net electrode current is constant, it will be seen that its potential will also remain constant notwithstanding ultra high frequency variations of the primary beam. As a result, the feedback coupling is practically eliminated, and the path which the electrons follow in passing from one electrode to another can be more accurately predetermined, since the electrons are influenced only by the static D. C. fields produced by the biasing potentials.

Specifically, two arrangements are herein proposed for maintaining the secondary emissive

electrodes at constant potentials. In accordance with one embodiment of this invention, two parallel electron beams are passed through the multiplier, each electrode being subjected simultaneously to the effect of the two resulting streams of electrons. By modulating the intensity of the two primary electron beams equally and oppositely, one beam compensates for the effect of the other. In an alternative system, the intensity of the beam is held constant and modulation is provided by a lateral displacement which merely changes the point of impact of the electrons on each electrode. In both cases a split output electrode provides amplified output currents which, in the first case, are determined by the relative intensities of the beams, and, in the second case, are a function of the position of the beam, and hence of the modulating voltage.

It is accordingly an object of this invention to provide means for maintaining constant the potential of the secondary emissive electrodes of an electron multiplier, notwithstanding the modulation of the primary electron beam.

Another object is to provide a secondary electron multiplier which is efficient and reliable when operated at ultra high frequencies.

Another object of this invention is to provide a high gain amplifier suitable for operation at frequencies of the order of several hundred megacycles.

A still further object of this invention is to maintain the electrode potentials constant by modulating two electron beams equally and oppositely, and passing these beams along parallel paths through the multiplier.

A still further object of this invention is to provide an electron multiplier in which modulation of the primary electron beam is accomplished by deflecting it transversely across the secondary emissive surfaces.

Other objects of this invention, as well as a more complete understanding of its nature and operation, may be obtained by considering the following description in connection with the accompanying drawing, and its scope is indicated by the appended claims.

Referring to the drawing, Figure 1 is an embodiment of this invention utilizing parallel electron beams; Figure 2 is an embodiment which employs the principle of transverse deflection; Figure 3 is an embodiment employing photoelectric means for generating the primary electron stream; and Figure 4 is an oscillator utilizing the parallel beams principle of operation. Similar reference numerals refer to similar parts throughout the drawing.

This invention will be explained by reference to an electron multiplier of the type illustrated in a copending application of Pike, Rajchman and Snyder, Serial No. 205,672, for "Electron multipliers," filed May 3, 1938, now Patent No. 2,198,227, April 23, 1940. However, this invention is equally applicable to other multipliers, including the one shown in the above-identified Malter Patent No. 2,073,599. The principal difference between the two multipliers is that Pike, et al., employs arcuate electrodes and no magnetic field, while Malter employs flat surfaced electrodes and a magnetic field. Operation at high frequencies with either type is equally difficult, and the cure is the same, however.

Referring to Fig. 1, the multiplier elements are mounted along the longitudinal axis of an elongated envelope **5**. A pair of electron guns **7**, **9** and a pair of grid electrodes **11**, **13** are mounted at one end of the device while a pair of anode electrodes **15**, **17** are mounted at the other end. A number of curved secondary electron-emissive or multiplying electrodes **19**, **21**, **23**, **25** and **27** are mounted in staggered relation on opposite sides of the longitudinal axis of the tube. The generatrices of the electrode surfaces are normal to a plane containing the longitudinal axis of the tube, and the concave emissive surfaces of the electrodes face inwardly.

The electron guns **7** and **9** are of the type used to produce a narrow beam of electrons in cathode ray tubes, for example, and may include suitable accelerating and focusing electrodes which, for the sake of simplicity, have not been illustrated. The guns are positioned so as to cause parallel beams of electrons to pass through the respective grid electrodes **11** and **13** and impinge at separate points on the first secondary emissive electrode **19**.

For the purpose of providing a suitable static potential distribution between adjacent electrodes, the electron ray guns are grounded, while the multiplying electrodes are connected to points of successively increasing potential along a pair of voltage dividers **29** and **31**, the high potential ends of which are connected to the positive terminal of a suitable D.-C. source **33**, the negative terminal of which is connected through a biasing resistor **35** to ground. The highest positive voltage is applied to the two anode or collecting electrodes **15** and **17**, by means of a connection intermediate the ends of the primary **39** of an output transformer **37**. A suitable negative bias is applied to the two grid electrodes by means of a connection from the bias resistor **35** to a point intermediate the ends of the secondary **41** of an input transformer **43**.

The specific design and constructional details of the secondary emissive electrodes has been given in great detail in the above-identified Pike, et al., patent application, and need not be repeated herein. However, it is important to note that the electrons released from the first emissive electrode are focused without any numerical diminution upon the next succeeding electrode and thereby give rise to a new and augmented group of secondary electrons, which are, in turn, focused without loss upon the next succeeding electrode. Consequently, electrons will flow from the initial points of impact on electrode **19** in parallel paths without mixing, and will eventually impinge on the respective anode electrodes.

In accordance with this invention, a radio frequency voltage which is to be amplified, or detected and amplified, is impressed on the input transformer **43** so as to be equally and oppositely applied to the two control grid electrodes **11** and **13**. The primary electron beams will be accordingly modulated in intensity, and this modulation will be successively amplified at each secondary emissive electrode. However, since each emissive electrode is subjected to the equal and opposite fluctuations of two electron streams, the net change of potential of each electrode, due to the changing influx and efflux of electrons, is zero. Otherwise considered, the effect of the one electron beam cancels the equal and opposite effect of the other beam. Only a direct current flows through the leads which connect each electrode to the source of energy and consequently the reactance of the lead, and hence the voltage drop in it, is negligible.

As the two amplified beams are received on

separate anode electrodes which are connected in push-pull to the output transformer 37, a greatly amplified output voltage is available at the output terminals. The device may be operated over a linear portion of the grid voltage vs. beam current characteristic for amplification, or it may be operated on the elbow of the characteristic curve for detection. In either case, the interelectrode capacities are of no importance, since there is no alternating potential between the tube electrodes.

Another arrangement for maintaining the emissive electrodes at a constant potential notwithstanding modulations of the beam is illustrated in Fig. 2, to which reference is now made. The tube structure differs from that illustrated in Fig. 1 by the inclusion of but a single electron gun 7 and the substitution of a pair of deflecting plates 45, 47 for the grid electrodes 11 and 13. For simplicity, only a part of the tube has been shown, since the output portion is the same as that illustrated in Fig. 1.

The electron gun 7, of Fig. 2, is preferably centrally located, and, when suitably energized, the gun directs a beam of electrons at the first emissive electrode 19. The electrons released from the first electrode pass on to the next, and ultimately a greatly increased beam of electrons reaches the far end of the tube. If the beam is still centrally located, the electrons will either pass between the two anode electrodes or a part of them will pass between, while a part will impinge on the two anodes, depending on the diameter of the beam and the geometry of the anodes. In order to provide a more uniform change as the beam is deflected the output electrode may be divided diagonally.

Modulating voltages are applied in phase opposition between ground and the two deflecting plates, so that the primary electron beam is deflected transversely across the first emissive electrode in a plane perpendicular to the tube axis. Consequently, the position of the electrons impinging upon the anode electrodes will vary in accordance with the modulating voltage. As the greatly amplified beam alternates its position from one anode 15 to the other 17, an amplified output voltage will be induced in the secondary of the output transformer 37.

It is to be noted that the beam amplitude is not modulated in this modification, but only its position. The net gain or loss of electrons at any given emissive electrode is a function of its amplitude, but not of its position, assuming uniform emissive qualities over the surface of the electrode. Consequently, there is no alternating potential difference between adjacent electrodes. A further advantage of the arrangement illustrated is that the modulating control is affected by the deflecting plates 45 and 47 which are not actually in the electron stream. This means that a higher input impedance may be obtained than is possible with the grid type control.

The primary electron beam need not originate at a thermionic gun, but may be attained by photoelectric means, as illustrated in Fig. 3, to which reference is now made. In this figure, the secondary emissive electrode and output structure is similar to that illustrated in the preceding figures although not repeated in this illustration. The primary electron source, however, comprises a light source 49 and a lens 51 for focusing a pencil of light on the photosensitive surface of an arcuate electrode 53. The released electrons are attracted to the first secondary electron-emissive electrode 21 by its relatively high positive potential. A pair of deflecting plates 45, 47 are provided, as before, to deflect the primary beam across the electrode. The deflecting electrodes may be given a slightly negative bias. Otherwise, the operation of this modification is the same as that of the preceding figure.

Fig. 4 illustrates an arrangement the tube structure of which is identical to that of Fig. 1, but which includes a link-coupling circuit 55 between the input and output of the multiplier. When the connections are suitably phased, it will be recognized that the multiplier will oscillate at a frequency determined primarily by the resonant frequency of the input and output circuits 57 and 59. The same feedback can, of course, be applied to the deflection type of amplifier to produce high frequency oscillations.

One advantage of the oscillator illustrated in Fig. 4 is that it may be designed to generate large amounts of power at extremely high frequencies. Tubes of ordinary construction which are designed for large power output necessarily have large electrodes, and the resultant interelectrode capacities prevent its operation at high frequencies. On the other hand, when the size of the electrodes is reduced to permit operation at high frequencies, the tube is on longer able to provide large amounts of power, due to the decreased area of radiation. In the present tube, however, the deleterious effect of the interelectrode capacity has been overcome, and the electrodes can be designed as large as desired to provide substantial power output without in the least reducing the efficiency of the tube at high frequencies.

I claim as my invention:

1. In a device of the character described, means for producing a beam of electrons, a plurality of secondary emissive electrodes, means for applying biasing potentials to said electrodes, said beam of electrons being normally focused on the first of said secondary emissive electrodes to release electrons therefrom which pass to each successive electrode, means for varying the position of said beam of electrons on said first electrode to produce a corresponding change in the position of electrons impinging on each of said secondary emissive electrodes, and means for deriving an output voltage corresponding to said position variations.

2. In a device of the character described, means for producing a beam of electrons, a plurality of secondary emissive electrodes, means for applying positive potentials to said electrodes, said beam of electrons being normally focused on the first of said secondary emissive electrodes to thereby cause the release of secondary electrons therefrom, said secondary electrons passing successively to each secondary emissive electrode, means for deflecting said electron beam transversely over said first electrode in accordance with a deflecting voltage to cause a constant number of said electrons to impinge on each of said electrodes at different points, and output means for deriving an amplified output voltage which is a function of the deflection of said beam.

3. In a device of the character described, means for producing a beam of electrons, a plurality of secondary emissive electrodes, means for causing electrons liberated from one of said electrodes to pass to a successive electrode, means for normally focusing said beam of electrons on the first of said electrodes to initiate a flow of a constant number of electrons from

one of said electrodes to another, a pair of collector electrodes positioned so as to intercept electrons from opposite halves of the last of said secondary emissive electrodes, an output circuit connected between said collector electrodes, and means for deflecting said beam of electrons transversely across said first electrode in accordance with a signal to cause electrons to be emitted from one or the other half of said last electrode.

4. The combination which includes means for producing a beam of electrons of constant amplitude, a plurality of secondary emissive electrodes, means for causing said beam to impinge on one of said electrodes to release secondary electrons therefrom, means for causing a constant number of electrons liberated from said one electrodes to pass successively to each of the other emissive electrodes, means for deflecting said beam transversely across said one electrode in accordance with a modulating voltage to cause said electrons to impinge at different points on each successive electrode, and a pair of collecting electrodes adjacent the last of said emissive electrodes to intercept electrons released from different portions of said last emissive electrode, and means connected to said output electrodes for deriving an amplified voltage which is a function of said modulating voltage.

5. In an electron discharge device the combination including means for producing a beam of electrons of constant intensity, a plurality of secondary emissive electrodes, means for focusing said beam on the first of said emissive electrodes to cause secondary electrons to be released therefrom, means for focusing said secondary electrons on a successive emissive electrode to release other secondary electrons, means for deflecting said beam across said first electrode to cause the point of impact of electrons on each emissive electrode to vary accordingly, the number of electrons impinging on each electrode being constant, and output electrode means for collecting a number of electrons from the last of said emissive electrodes which is a function of the deflection of said beam.

JAN A. RAJCHMAN.