Nov. 5, 1940. E. G. LINDER 2,220,161

ELECTRON MULTIPLIER

Original Filed Nov. 30, 1935

Fig. 1

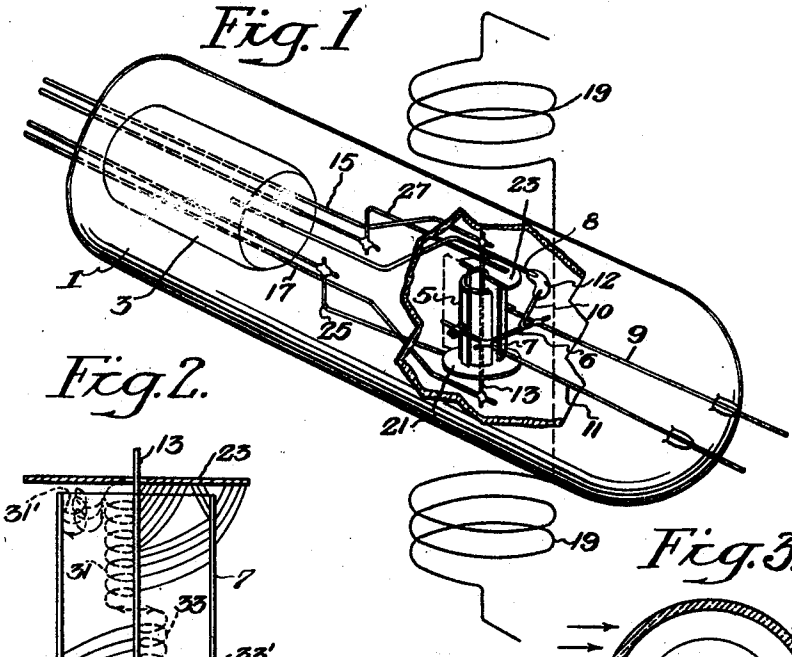


Fig. 2.

Fig. 3.

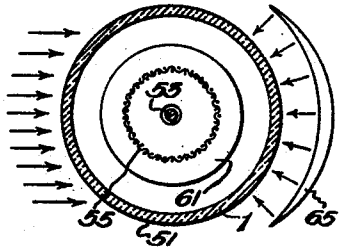
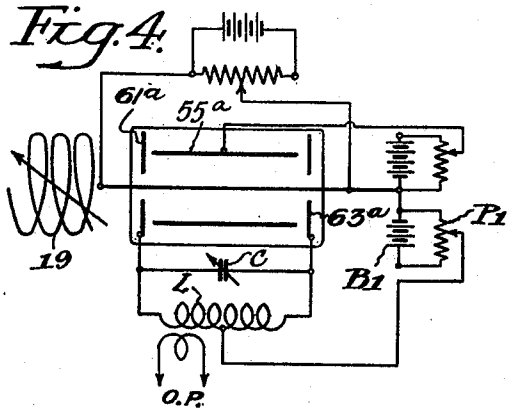


Fig. 4.



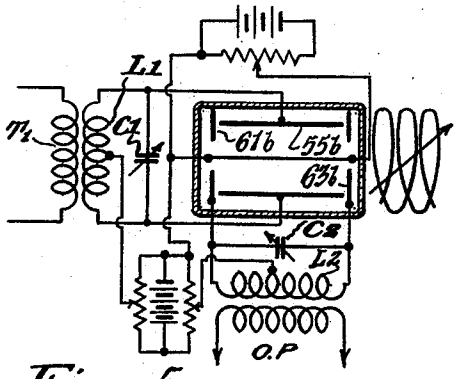


Fig. 5.

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2,220,161

ELECTRON MULTIPLIER

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Original application November 30, 1935, Serial No. 52,299, now Patent No. 2,156,264, dated May 2, 1939. Divided and this application December 24, 1937, Serial No. 181,508

5 Claims. (Cl. 179—171)

This is a division of application Serial No. 52,299, filed November 30, 1935, now Patent No. 2,156,264, May 2, 1939.

My invention relates to circuits for electric discharge devices and particularly to circuits for devices 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.

If an electrode is subjected to electron bombardment it will emit secondary electrons. The ratio of the number of secondary electrons to the number of primary electrons depends, in part, upon the character of the bombarded surface, and upon the potential difference between the surface and the source of electrons. For example, a ratio of five or more secondary electrons to one impinging electron is readily obtainable with metallic surfaces treated in known ways and subjected to discharges at potentials of 300 to 400 volts.

The use of electron-multipliers in the detection, amplification and generation of relatively low radio-frequency waves has been attended with considerable measure of success in recent years. Attempts to apply prior art tubes of the type described to ultra-short wave work (say 10 centimeters), however, have either failed entirely or have resulted in unreliable and inefficient operation either because of the large capacitance occasioned by the very presence of the multiplying electrodes, or because their position with respect to the other electrodes has been such as to make the electron transit time of long duration.

It is, accordingly, an object of my invention to provide an improved electric discharge device, utilizing secondary electron emission that shall be responsive to waves of ultra-high frequencies.

Another object of my invention is to provide an electron-multiplier wherein the inter-electrode capacitance and the electron transit time shall be of small magnitude.

Another object of my invention is to increase the ratio of secondary to primary electrons in electron multipliers employing secondary electrodes of a given emissive constant.

A further object of my invention is to improve the efficiency of ultra-short wave oscillators.

Other objects will be apparent and the invention itself both as to its organization and method of operation will be best understood by reference to the following specification and to the accompanying drawing wherein:

Figure 1 is a perspective view of an electron-discharge device embodying my invention, the envelope of the tube being broken away in part in order to show the internal structure more clearly,

Figure 2 is a cross sectional view of the electrode assembly of Fig. 1 taken on the long axis of the tube of that figure and which is referred to in explaining the operation of the device,

Figure 3 is a cross sectional view of device within the invention, employing a photo-sensitive cathode and a unitary anode,

Figure 4 is a circuit diagram illustrating one manner of connecting the device for the generation of oscillations of ultra-high frequencies, and

Figure 5 is a circuit diagram illustrating one manner of connecting the device for amplifying oscillations of ultra-high frequencies.

In carrying my invention into effect, I may employ a tube similar in many of its constructional details to that disclosed in my application, Serial No. 703,346, filed December 21, 1933. Such a device is illustrated in Fig. 1, which shows a magnetically controlled tube of the split-anode type which comprises a highly evacuated envelope 1 having a press 3 for supporting certain of the electrodes. Two anode plates 5 and 7 are provided, each plate being in the form of a half cylinder. Anodes 5 and 7 are supported from conducting rods 9 and 11 which are sealed into the end of the envelope 1 opposite the press 3, these rods forming a transmission line for conducting energy outside the tube envelope.

Additional support for the anodes 5 and 7 is provided in the form of a rod 6 which mechanically and electrically connects the conductors 9 and 11 at points which are nodal points on the said conductors when the tube is operated at the high frequency for which it is designed. The rod 6 is supported at the middle from a supporting rod 8 by means of a rod 10 and glass bead 12. In addition to functioning as a support for the anodes, the rod 6 acts as a short circuit between them for oscillations having a lower frequency than the desired frequency.

The cathode 13 consists of a straight thermionic filament which is co-axially positioned with respect to the anode plates 5 and 7 and supported at each end by conductors 15 and 17 sealed into the press 3.

A strong magnetic field of constant intensity is provided by means of magnet coils 19 which, preferably, are so positioned that the lines of force of the magnetic field are parallel to the axis of the anode plates and filament. It should be understood, however, that the lines of force

CROSS REFERENCE SEARCH ROOM

may be at an angle with respect to the axis of the anode plates.

In accordance with my invention, I provide electro-static end-plates 21 and 23 having their inner surfaces suitably treated as by the application of caesium or equivalent electron-emissive substance to render them secondarily emissive. These plates 21 and 23 are positioned at opposite ends of the anodes 5 and 7 in any suitable manner as by means of rods 25 and 27, respectively, extending from the press 3. These secondarily emissive end-plates are maintained at a positive potential with respect to the filament 13. In general, the two electrostatic plates will be maintained at the same potential, although in some cases it may be desirable to give them a certain potential difference.

The operation of my improved electron-multiplier will be understood by reference to Fig. 2, which is a cross sectional view on an enlarged scale of the electrodes shown in Fig. 1. The approximate distribution of the electrostatic lines of force is here indicated, this distribution being that of the electrostatic field which is in the plane of the paper. In order to simplify the drawing, the lines of force are not indicated in the upper left-hand and the lower right-hand portions of the figure. In this figure, as in Fig. 1, the filament is indicated at 13, the anode at 7 and the secondarily emissive end-plates at 21 and 23.

The spiral dotted lines 31 running in an upward direction parallel to the filament, and those designated 33 running in similar paths but in the opposite direction show typical primary electron paths when the magnetic and electrostatic fields are of an intensity such that the device is operating at its highest efficiency. Under these conditions the primary electrons 31, 33 emanating from the filament travel in spiral paths toward the nearest end plate. The limit of the path in a direction normal to the filament is determined by the adjustment of the magnetic field and to some extent by the potential applied to the anode. In no case is the intensity of this field or the anode potential such as to permit the primary electrons to graze or otherwise contact the anode 7. As indicated, the primary electrons are accelerated toward the end plates by the electrostatic field generated by these electrodes so that in impinging thereagainst they release secondary or "impact" electrons 31'—33' from these emissive surfaces. The secondary-electrons 31'—33', so released, are in turn attracted to the more positively charged anode 7. In their travel to this terminal electrode they too circumscribe curved paths.

One very real advantage of electron-multipliers constructed in accordance with the principles of my invention is this: the ratio of secondary electrons to primary electrons is greater than that obtaining in devices constructed and operated in accordance with the prior art. This is so because the vast majority of the primary electrons (31—33) necessarily strike the secondarily emissive electrodes 21—23 at an acute angle whereby they "ricochet" or graze these surfaces releasing more secondary-electrons than would be the case if they struck these surfaces in a direction normal thereto. Incidence at an acute angle results in greater efficiency for high velocity electrons because the penetration into the metal is less whereby the secondary-electrons escape more readily.

The described phenomenon is especially advantageous where the tube is employed in ultra-high frequency work for under such conditions it is not always practical to incorporate a plurality of successive multiplying stages in a single envelope as is the practice in tubes designed to deal with lower frequencies.

It is not to be inferred from the foregoing description that my invention is to be limited to the precise embodiment illustrated by Fig. 1. Quite obviously, a unitary anode may be substituted for the bi-part electrode 5—7 of this figure and the di-pole conductors 9 and 11 dispensed with. Further, as shown in Fig. 3, I may utilize a photo-sensitive electrode 53 as the source of primary-electrons instead of the thermionic filament 13 of Fig. 1. In this cross sectional view of a structure embodying my invention the electrodes are symmetrically disposed about a central axis of a transparent envelope 1; the photo-sensitive primary source 53 defining this axis is completely surrounded by a unitary open ended cylindrical anode 55. This anode 55 is of wire mesh or other foraminous construction to permit light (which may be either steady or fluctuating in character) from an external source, not shown, to impinge upon the light sensitive cathode 53. A reflector 65 is preferably provided for directing the light rays, indicated by the arrows, over the entire surface of the cathode. An end plate 61 is positioned adjacent, but not touching, each open end of the anode, as described in connection with Fig. 1 the inner surfaces of these electrodes are treated with caesium or other suitable material to render them secondarily-emissive.

Fig. 4 shows diagrammatically a device within my invention arranged as a generator of ultra-high frequency oscillations. The anode 55*a*, which may here be assumed to be of unitary construction, is not an output electrode but serves to accelerate the primary electrons and to collect the secondary electrons from the emissive electrodes. Use is here made of the negative resistance characteristic which obtains in the end plate circuit by reason of the secondary-emissive characteristic of these electrodes 61*a*, 63*a*. A tuned circuit L—C is connected between the end plates and the output taken off by a suitable coupling device symbollically indicated by the coil O. P. As indicated by the arrow superimposed upon magnetic coil 19 and by the potentiometer P1 across the energizing source B1 for the end plates the intensity of the electromagnetic and of the electrostatic fields may be adjusted to ensure optimum performance.

Fig. 5 shows diagrammatically a device within my invention arranged as an amplifier of ultra high frequency oscillations which are impressed as by means of a transformer T1 upon the tuned anode circuit L1 C1. Here the electrostatic and magnetic fields are so adjusted that the electrons revolve in their orbits at a frequency equal to that of the oscillations impressed upon the anode 55*b*. When the frequencies are equal resonance is achieved between electron motion and the applied oscillatory voltages, this results in absorption of energy by the electrons so that they strike the end-plates 61*b* and 63*b* with increased velocity thereby ejecting more secondary electrons. As a result of the increased secondary-emission the "steepness" of the negative resistance characteristic is increased whereby the oscillations appearing in the tuned output circuit L2 C2 are of increased amplitude.

Various structural and circuit modifications will suggest themselves to those skilled in the art.

It is to be understood, therefore, that the foregoing is to be interpreted in an illustrative and not in a limiting sense except as required by the prior art and by the appended claims.

I claim as my invention:

1. The combination with an electron multiplier comprising a source of primary electrons, a pair of secondary-electron emitter electrodes and a pair of collector electrodes, means for directing primary-electrons from said source to said pair of emitter electrodes and for directing secondary-electrons from said emitter electrodes to said pair of collector electrodes, a tuned circuit connected between said collector electrodes for impressing a radio frequency voltage thereon and a second circuit adapted to be tuned to the said frequency, connected between said emitter electrodes.

2. In combination, an electric discharge device comprising a cathode, and an anode disposed about a common axis, a pair of secondary-electron emissive electrodes disposed adjacent opposite ends of said anode in planes normal to said axis, means for establishing an electrostatic field in the space between said end plates, means for inducing a magnetic field in said space, means for adjusting the relative direction and intensity of said electrostatic and magnetic fields to cause primary electrons from said cathode to travel in spiral paths to said end plates and to release secondary electrons therefrom by impact excitation, and means for maintaining said anode electrically positive with respect to said end plates whereby said secondary electrons are drawn thereto.

3. In combination, an electric discharge device comprising a cathode and an anode disposed about a common axis, a pair of secondary-electron emissive electrodes disposed adjacent opposite ends of said anode in planes normal to said axis, means for establishing an electrostatic field in the space between said end plates, means for inducing a magnetic field in said space, means for adjusting the relative direction and relative intensity of said electrostatic and magnetic fields to cause primary electrons from said cathode to impinge upon said end plates and to cause secondary electrons from said end plates to travel to said anode, and a tuned circuit connected between said end plates for utilizing the emission of secondary-electrons from said end plates to establish electrical oscillations in said tuned circuit.

4. In combination, an electric discharge device comprising a cathode and a bipart anode disposed about a common axis, a pair of secondary electron emissive electrodes disposed adjacent opposite ends of said anode in planes normal to said axis, a tuned circuit for impressing a radio frequency voltage between the parts of said anode, a circuit tuned to said radio frequency connected between said end plates, means for establishing an electrostatic field in the space between said end plates, means for inducing a magnetic field in said space, means for adjusting the relative direction and intensity of said electrostatic and magnetic fields to cause primary electrons from said cathode to travel in spiral orbits to said end plates at an orbital frequency substantially equal to that of the radio frequency oscillations impressed upon said anode whereby said primary-electrons strike said end plates with velocity such as to ensure the release of the optimum quantity of secondary-electrons therefrom, and whereby the secondary-electrons emitted from said end plates and flowing in the said anode circuit will vary in accordance with the frequency impressed thereon.

5. Method of operating a magnetron having a pair of end plates which comprises directing the primary electrons from the cathode in spiral orbits to the end plates at a desired orbital frequency whereby the primary electrons impinge upon the end plates and release secondary electrons therefrom, and drawing the secondary-electrons to the anode whereby said secondary-electrons produce oscillatory currents of a frequency corresponding to said orbital frequency.

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