Aug. 30, 1938. P. T. FARNSWORTH 2,128,580

MEANS AND METHOD OF OPERATING ELECTRON MULTIPLIERS

Filed Aug. 18, 1936 2 Sheets-Sheet 1

Fig. 1.

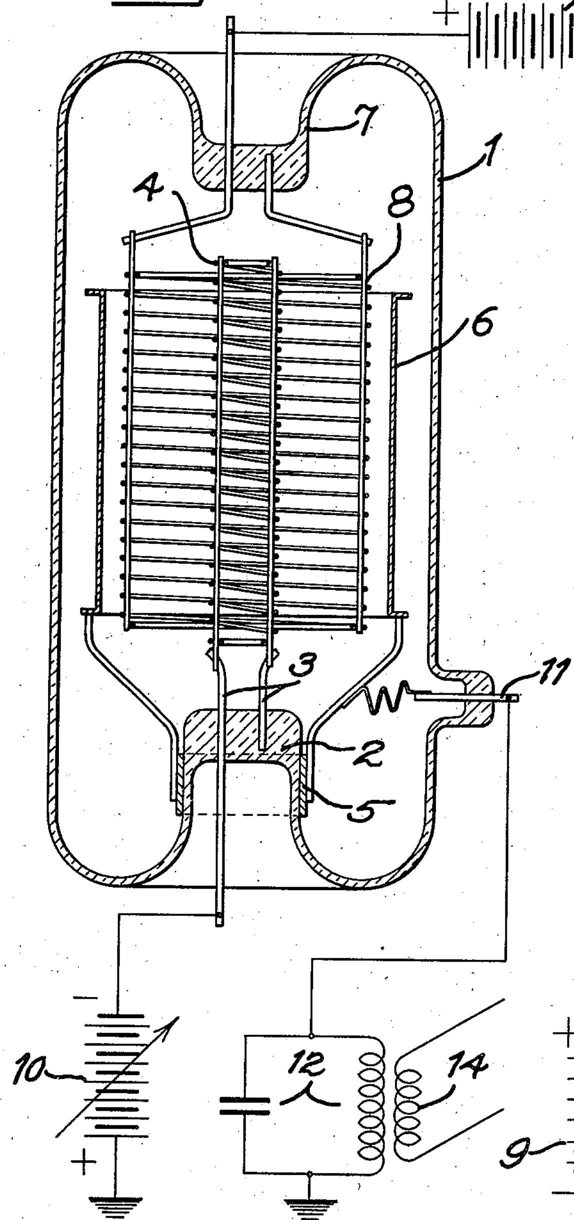

Fig. 2.

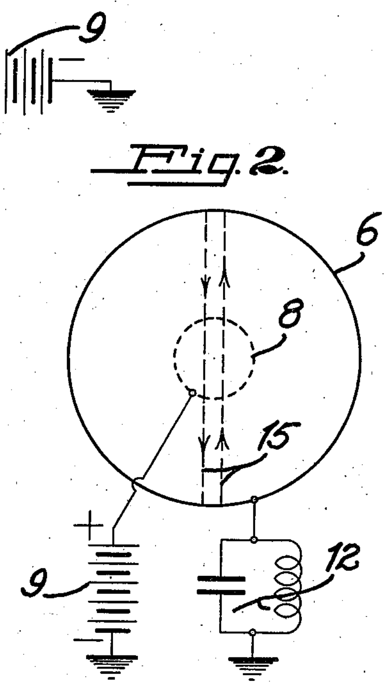

Fig. 4.

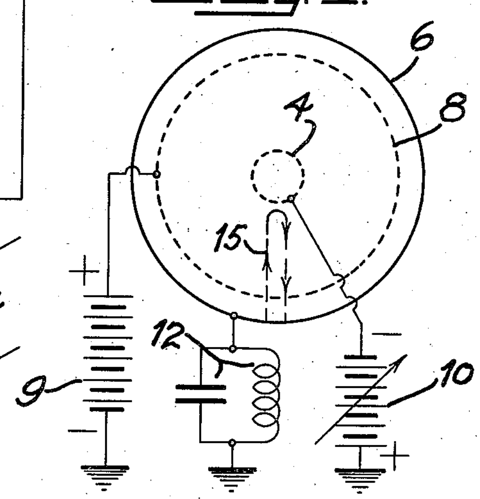

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Fig. 3.

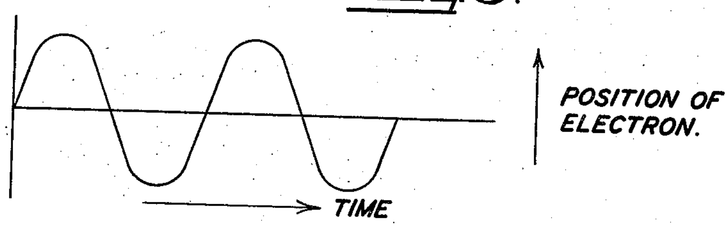


Fig. 5.

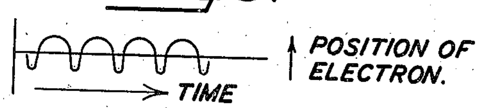


Fig. 6.

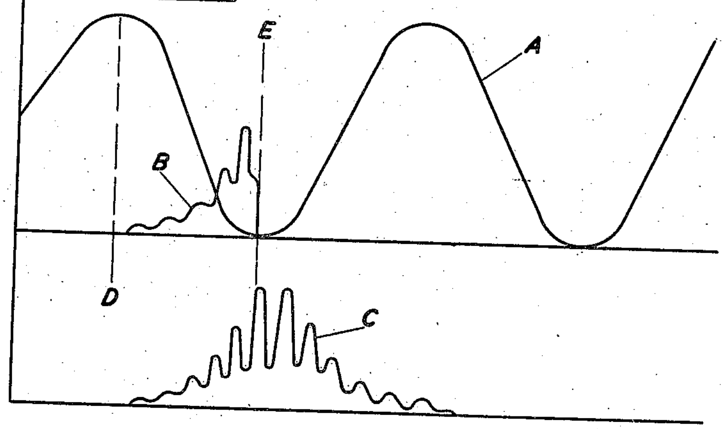
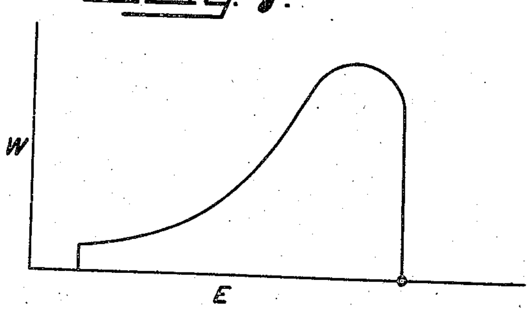


Fig. 7.



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UNITED STATES PATENT OFFICE

2,128,580

MEANS AND METHOD OF OPERATING ELECTRON MULTIPLIERS

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Application August 18, 1936, Serial No. 96,614

11 Claims. (Cl. 250—36)

My invention relates to a means and method of operating an electron multiplier, and particularly that form of electron multiplier having as fundamental structure a secondarily emissive cathode surface and an accelerating anode spaced from and paralleling the anode surface.

Fundamentally my invention has to do with the form of electron multiplier I term a multipactor, in that amplification is obtained by repeated and cyclical electron impacts with a cathode surface adapted to emit secondary electrons at a ratio greater than unity. Ordinarily impacts take place only once per cycle of the impressed or primary frequency.

The present invention relates to a method of operating a multipactor in such a manner that there are multiple electron impacts during each cycle of operation of the device, thus giving rise to what I shall term an electron frequency. As a consequence, this electron frequency being greater than the primary frequency, harmonics having large power may be obtained.

Among the objects of my invention, therefore, are: To provide a method of operating a multipactor to give multiple secondary electron generating impacts per primary cycle; to provide a method of obtaining harmonics containing a large power output in an electron multiplier; to provide a method of generating harmonics; to provide a means and method of regulating the harmonic output in a multipactor; to provide a method of controlling the length of path and consequently the time of flight in an electron multiplier; to provide a method of operating a multipactor wherein there is a single secondary electron emissive surface; to provide a method of operating a cylindrical electron multiplier wherein the electron paths are substantially radial; to provide a method of confining the time of flight to a short period compared to the primary period of an electron multiplier; and to provide a simple and efficient method of operation of an electron multiplier, having a single anode and a single cathode as a fundamental structure.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

Referring to the drawings:

Figure 1 is a sectional view of a multipactor structure which may be used to practice my method, together with a schematic circuit indicating the proper operative connections.

Figure 2 is a diagram of a diode multipactor operating where the transit time is the same as the primary frequency.

Figure 3 is a graph showing the position of the electron with respect to time in a multipactor operated in the circuit of Figure 2.

Figure 4 is a diagram showing a diode multipactor together with an auxiliary electrode for operating the device with an electron transit time short relative to the primary period.

Figure 5 is a graph showing the position of the electron with respect to time as shown by the operating characteristics of the oscillator shown in Figure 4.

Figure 6 is a graph showing the relative characteristic curves of a multipactor connected as shown in Figure 4.

Figure 7 is the over-all power-voltage characteristic of the multipactor oscillator.

This application is a continuation in part of my application Serial No. 80,193 filed May 16, 1936, wherein an auxiliary electrode was described as utilized to collect ions in a space wherein electron multiplication was taking place. Some gas ions are always present, and when alkali metal surfaces are used for the creation of secondary electrons, metal ions will also be present within the envelope containing the multipactor structure. During the operation of the device, these ions tend to bombard the cathode, thus tending to cause damage to the cathode and a reverse current opposing the desired current, and because of the slow speed of the ions this current will be of any phase. An auxiliary electrode, as described, negatively charged and placed near the operating space of the multiplier, will collect such ions before they can enter into the operation of the device. In that application I touched only upon the use of this auxiliary electrode for ion collection, but in the present application, while said auxiliary electrode is used for ion collection, it is also positioned and energized to control the length of the electron paths within the multipactor and thus control its time of flight. It is obvious that as an ion collector this auxiliary electrode may be positioned and energized in other locations and to other potentials than are herein to be described, whereas in the present application this ion collector must have a certain position with respect to the other electrodes in order to perform the method I am herein disclosing.

For a simple multiplier structure capable of practicing my present method of controlling the electron flight, direct reference is made to Figure 1, which is substantially the same structure as referred to in my prior application mentioned above. An envelope 1 is provided at one end with a re-entrant stem 2 through which pass auxiliary electrode supports 3, supporting a central and preferably axial cylindrical grid structure 4. This stem also supports by means of a peripheral ban 5 a cathode 6 in the form of an unperforated cylinder having its inner surface sensitized to produce secondary emission at ratios greater than unity when being impacted by electrons traveling at a velocity of 20 volts or greater, although, for the purposes of my method such sensitivity is not required but is desirable. I may, however, make this cathode of a nickel barium alloy such as has been described in my patent application Serial No. 70,714, filed March 24, 1936.

The opposite end of the tube also has a re-entrant stem 7 sealed thereto supporting a grid-like anode structure 8, which may be formed as shown of the spiral wire welded to supports, or may be a perforated sheet metal assembly, the main point being that it should be perforated to allow electrons to pass toward the axis of the assembly. Anode 8 is energized to a high potential, preferably several thousand volts, by means of anode source 9, the negative end being grounded. The auxiliary electrode 4 is energized through an auxiliary source 10, preferably variable, this source energizing the auxiliary electrode to a negative potential, the positive end being grounded. The cathode 6 has a lead 11 passing through the wall of the envelope, this lead going to a tuned circuit 12, the other end being grounded, thus placing a tuned circuit directly across anode and cathode and providing the main or primary frequency. An output circuit 14 is coupled to the tuned circuit 12, and this output circuit may lead to transmission line or other device as will be explained later. The device is now ready for operation as a self-oscillator if desired, or may be driven if desired, and in this latter instance coil 14 is used to supply the primary frequency between the cathode and anode.

To more fully understand the method of operation of my device I prefer to refer directly to a diagram as shown in Figure 2, which represents a fundamental electron multiplier structure using a single anode and a single cathode, wherein the time of flight of the electron determines the output frequency. In this case the tuned circuit 12 is designed to have a period equal to a time of flight which is substantially diametrical, and in addition, anode source 9 is adjusted so that the acceleration given to the electron will bring the electron across the cathode space in the period selected. In other words, the potential of anode source 9 and the period of tuned circuit 12 should be adjusted so that the time of flight corresponds to the period.

In this type of multiplier the anode 8 is made considerably smaller than the cathode 6, thus giving an acceleration toward the axis of the device. When hooked up in this way the position of the electron with respect to time will be that as shown in Figure 3, the electrons leaving the cathode at one point, passing near the axis of the cathode cylinder 6 and impacting the opposite side of the cathode to produce secondaries, these secondaries then returning past the axis to again impact the cathode on an opposite surface, as indicated by dash lines 15 in Figure 2. This action, of course, takes place along all diameters and the output current will have its greatest power in the primary frequency as determined by the adjustments and by tuned circuit 12, and there will not be a large harmonic content.

My present method of operation however, is quite different. It will be seen that in the operation of the simple multipactor just described immediately above, there is only one secondary electron generating impact per primary cycle, and I have therefore operated my device in an entirely different manner as shown in Figures 4, 5, 6 and 7. Figure 4 will be found to be a diagram representing schematically a sectional view of Figure 1 and in this case I have shown the electron path 15 as being a radial path rather than a diametrical path. This is due to the fact that the anode 8 is placed relatively close to the emitting surface of cathode 6 and is therefore much larger in diameter, and that there is a negative potential on the inner auxiliary electrode 4. Thus, as an electron leaves the cathode it is accelerated by the anode and passes therethrough toward the axis and toward the negatively charged electrode 4, which rapidly decelerates the electron which, in addition, is being decelerated by traveling away from anode 8. The combination of these two potentials turns the electron around, drives it back through the anode to impact the cathode again at or near the cathode surface at which it originated, and it is quite obvious that the length of the path 15 can be controlled by amount of the negative potential impressed upon auxiliary electrode 4, and that if the length of the path is changed the time of flight will be changed without, however, changing the primary frequency.

The reason for this is shown in Figures 5, 6 and 7. Figure 5 is a graph showing the position of the electron with respect to time in my new method of the operation of the device, showing that there are multiple impacts with the cathode and that these impacts will be greater in number than the primary frequency.

In Figure 6 I have shown all three characteristic curves of the multipactor operating under my new method. Curve "A" represents the primary frequency graphed as the difference of potential between cathode and anode; curve "B" is the current flowing out of the cathode due to secondary emission; and curve "C" is the current collected at the anode.

These curves co-operate as follows: At or near the maximum difference of potential between cathode and anode as indicated by dash line "D", secondary emission begins, first with a one-to-one ratio, the ratio then increasing up to the point of minimum difference of potential as indicated by dash line "E" where secondary emission will cease. I have found that no difficulty is encountered in obtaining, for example, maximum secondary emission ratios of four-to-one at the highest production of secondaries. At the minimum difference of potential between anode and cathode (point "E") the emission of secondaries ceases and the electrons generated oscillate back and forth through the anode, gradually lose velocity and are collected at the electron frequency, thus giving rise to an output current as shown in curve "C", the rising portion of this curve being formed by electrons being collected or intercepted by the anode as the generated secondaries pass therethrough at the electron frequency. Thus the primary frequency appears in the output current, and in addition to that primary frequency, it can be easily seen by an examination of curve "C" that there is an extremely high harmonic frequency, and by adjusting the potential on auxiliary electrode 4 the number of impacts per primary cycle can be readily controlled and thus the amount of current in any desired harmonic may be obtained. In that respect output circuit 14 as shown in Figure 1 may be utilized to draw one or more harmonics as desired to be used for predetermined purposes.

So high in power are the harmonics developed by operating the device in this manner that I have been able to obtain five or ten per cent of the output power at the tenth or twentieth harmonic. The property of harmonic generation is, of course, highly valuable for use in master oscillators or for ultra high-frequency work because the primary frequency may be relatively low and positively controlled much easier than can the harmonics themselves. Furthermore, the anode conversion efficiency of a multipactor operated as I have just described is extremely high, and for that reason the heat production is low, thus allowing high powered structures to be utilized in relatively small envelopes.

I claim:

1. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, and returning said electrons through said anode a plurality of times during a single period of the primary frequency.

2. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, and returning said electrons through said anode to contact said cathode a plurality of times during a single period of the primary frequency.

3. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, decelerating said electrons and returning them through the anode to contact said cathode with a velocity sufficient to create secondaries at a ratio greater than unity a plurality of times during a single period of the primary frequency.

4. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, and cyclically returning said electrons through said anode at a secondary frequency greater than the primary frequency.

5. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, cyclically returning said electrons through said anode at a secondary frequency greater than the primary frequency, and collecting a portion of the electrons on the anode during each passage therethrough.

6. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, cyclically returning said electrons through said anode at a secondary frequency greater than the primary frequency, collecting a portion of the electrons on the anode during each passage therethrough, and utilizing the collected current at said secondary frequency.

7. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, subjecting said electrons to a negative charge directed to return said electrons through the anode a plurality of times during a single period of the primary period, collecting a portion of the electrons on the anode at each passage therethrough to create a secondary frequency, and utilizing said secondary frequency.

8. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cathode to pass through said anode, subjecting said electrons to a negative charge directed to return said electrons through the anode a plurality of times during a single period of the primary period, collecting a portion of the electrons on the anode at each passage therethrough to create a secondary frequency, and varying the amount of said charge to vary said secondary frequency.

9. In an electron multiplier having an envelope containing a cathode adapted to emit secondary electrons at a ratio greater than unity upon electron impact therewith, and a perforated anode adjacent said cathode, the method of operation which comprises impressing a primary alternating potential between anode and cathode of sufficient intensity to cause electrons from said cath-

ode to pass through said anode, subjecting said electrons to a negative charge directed to return said electrons through the anode a plurality of times during a single period of the primary period, collecting a portion of the electrons on the anode at each passage therethrough to create a secondary frequency, varying the amount of said charge to vary said secondary frequency, and utilizing said secondary frequency.

10. The method of electron multiplication utilizing electron impact with a surface capable of generating secondary electrons at a ratio greater than unity which comprises moving electrons away from and against said surface capable of emitting secondary electrons at a ratio greater than unity and at a predetermined frequency to create successive secondary producing impacts, changing the impact velocity of each successive impact in accordance with a second predetermined frequency to create multiple impacts per cycle of said first predetermined frequency, and collecting the generated electrons at the first mentioned frequency.

11. The method of electron multiplication utilizing electron impact with a surface capable of generating secondary electrons at a ratio greater than unity which comprises moving electrons away from and against said surface capable of emitting secondary electrons at a ratio greater than unity and at a predetermined frequency to create successive secondary producing impacts, changing the impact velocity of each successive impact in accordance with a second predetermined frequency to create multiple impacts per cycle of said first predetermined frequency, collecting the generated electrons at the first mentioned frequency, and in varying amounts in accordance with the last mentioned frequency.

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