April 29, 1941. G. JOBST 2,239,678

SHOCK EXCITATION SYSTEM

Filed May 31, 1939

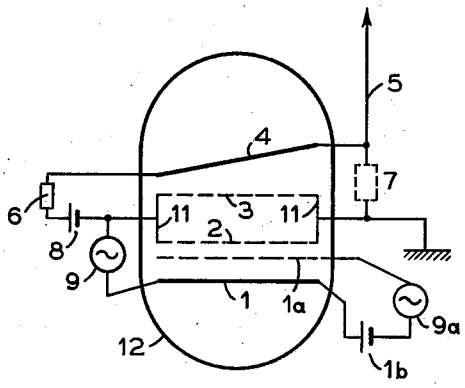


Fig. 1a

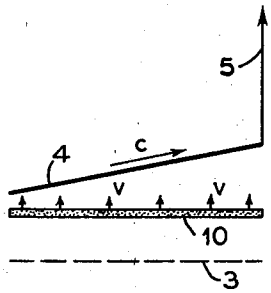


Fig. 1b

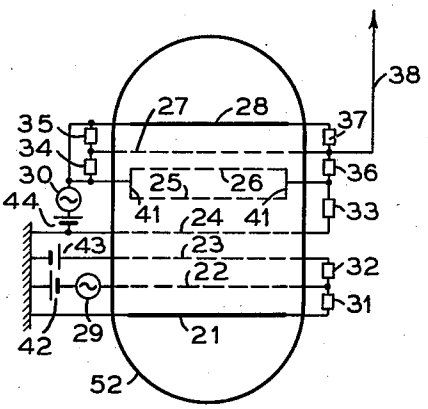


Fig. 2a

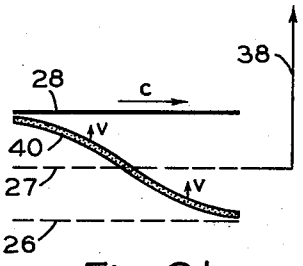


Fig. 2b

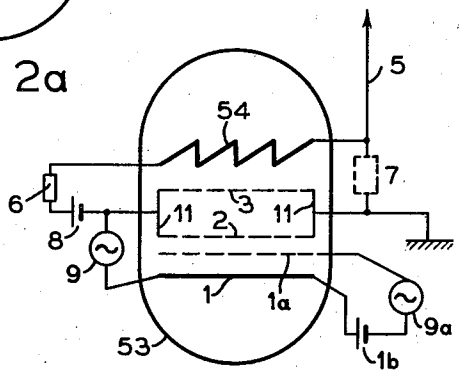


Fig. 3

INVENTOR
GUNTHER JOBST
BY Glascock Downing & Seebold
ATTORNEYS.

Patented Apr. 29, 1941 2,239,678

UNITED STATES PATENT OFFICE

2,239,678

SHOCK EXCITATION SYSTEM

Günther Jobst, Berlin, Germany

Application May 31, 1939, Serial No. 276,697
In Germany June 2, 1938

20 Claims. (Cl. 250—17)

This invention relates to a method and system for the shock excitation of short wave electromagnetic oscillations the wave length of which is so short that the voltage conditions on the electrodes of the electron discharge valve cannot be regarded as quasi-stationary.

In my copending application, Serial No. 209,595, filed May 23, 1938, which will be hereinafter briefly referred to as "my copending application," I have described a method for the shock excitation of oscillations by means of electronic valves in which sharply defined current impulses or shocks are produced in such a manner that charges produced during longer emission periods of the cathode are absorbed by the anode in periods of time which are very short compared to said emission periods.

The production of a larger output of oscillating electric energy requires a larger discharging cross section and larger electrodes, for, the current intensity of a single electron ray of a small cross section with a view to the space charge conditions cannot be increased beyond a certain amount; therefore, the charge of a single electron ray is small, even where means of the kind described in my copending application are used for compressing or compacting the electrons. Also, electrodes having a small area, more particularly small area anodes, are not suitable for radiating a larger amount of loss energy in the form of heat. The more the length of the waves is decreased compared to the dimensions of the electrodes, the less the potential on the electrodes, more particularly on the anode and the electrodes immediately adjacent thereto, can be regarded as quasi-stationary.

It is an object of the present invention to provide means for rendering the method according to my copending application suitable for the production of oscillations the wave length of which is so short that the voltage conditions on the electrodes can no longer be regarded as quasi-stationary.

According to the invention, the same means for preliminarily controlling and compressing the electrons as described in my above copending application are used for each cross sectional element of the discharging path, or for each of the elementary "strips" parallel to the path of the electrons, so that an electron "group," which is strongly compressed in time arrives at each cross sectional element of the anode. The arrival time which varies from one elementary strip to the next is controlled in such a manner that the impulses produced on the anode by the arrival of the single electron groups of each strip or, more precisely speaking, the temporally sharply defined ends of the current impulses coincide temporally in the antenna or are superimposed to be all in phase with each other in the antenna, in order that a sharply defined total impulse may be produced in the antenna. To this end, the elementary electron groups must arrive at the anode at different times, depending on the position of the respective elementary strip, in accordance with the travel along the anode of the voltage phase, so that the elementary current impulses induced in the anode by the arrival of the elementary electron groups may be all in the same phase with respect to the said voltage.

The invention will be better understood by reference to the following detailed description in connection with the accompanying drawing, showing by way of example and diagrammatically some embodiments of the invention.

In the drawing:

Fig. 1*a* is a diagram of a discharge system having the invention applied thereto.

Fig. 1*b* is a diagram showing the electron front as it travels towards the inclined anode of Fig. 1*a*.

Fig. 2*a* is a diagram of another discharge system having the invention applied thereto.

Fig. 2*b* is a diagram showing the travel of the electrons in a system, according to Fig. 2*a*.

Fig. 3 is a discharge system embodying an anode which consists of a plurality of inclined sections.

Referring first to Fig. 1*a*, there is shown a discharge tube 12 comprising a plane, plate-shaped cathode 1, two grids 2 and 3, arranged parallelly thereto, and a plate-shaped anode 4 forming an acute angle with the electrode 3. The grid electrodes 2 and 3 are interconnected within the tube at 11 and connected to a common voltage having a characteristic curve of such a shape that in each shock repetition period the electrons which have been emitted later from the cathode 1 arrive at the grid 3 approximately at the same time as those electrons which have been emitted earlier, during the same shock excitation period. This has been described in detail in my copending application.

As described in my copending application in a theoretically perfect tube for obtaining sharp pulses and having a cathode, control electrode and anode, the theoretically perfect control voltage for obtaining sharp pulses would be one applied to the control grid which would have a characteristic rising from zero with respect to

the cathode to an infinitely high positive value over a period of time and then dropping instantly to zero, at which moment the electrons would be absorbed by the anode. In this theoretically perfect tube the first electrons emitted by the cathode during the initial stages of the applied grid voltage would be the least accelerated and travel more slowly than the last electrons to be emitted by the cathode during any given period of applied voltage which last electrons would be accelerated to the greatest extent by the highest voltage on the grid so that when the control voltage reached a maximum of infinite value all of the electrons would be compressed into practically a plane of no depth. At this intant the control grid voltage would drop to zero so that electrons would pass as a group to the anode and be absorbed in substantially an infinitely small period of time creating a sharp pulse. A circuit having a natural frequency of oscillation harmonically related to that of the frequency of the pulses could then be excited. While such a theoretically perfect arrangement is not at present possible due to circuit and tube limitations, the applicant does approach this with the arrangement of electrodes in the tube and the circuits used for applying the control voltages as described in my copending application.

Explanation of the invention described in my copending application can be had by reference to Figure 1*a*. Electrons from the cathode **1** are subjected to the control of the first control grid **1***a*, so biased by voltage source **1***b* that electrons pass through this control grid only during a small portion of the positive cycle of the alternating voltage which may be applied by the alternating voltage source **9***a* connected between the cathode **1** and the control grid **1***a*. This group of electrons then passes to the control of the second control grid, in this case grids **2** and **3**, at the instant of time when the control grid voltage of the second control grid is rising in a positive direction and only during that portion of the rise which resembles a theoretically ideal voltage. This rising voltage variably affects the velocities of the group of electrons such that some are accelerated to a greater extent than the others, the last to approach the grid being accelerated to the greatest extent. At the instant of time when the voltage departs from the desired theoretically perfect characteristic, the electrons are directed into the field free space between grids **2** and **3** so that the electrons within this space continue to travel at the velocities they had upon entering this space. This results in the slow electrons being overtaken by the fast electrons so that very well defined groups of compressed electrons of very small depth result. The length of the field free space is chosen with respect to applied voltages and transit time of electrons such that upon emerging from the field free space the electrons will pass over and be absorbed by the anode before there is any noticeable dispersion of the electrons. This would be the result if the anode **4** were parallel to the grids **2** and **3**. Under these conditions the electrons would be absorbed by the anode in a comparatively short period of time. The effect upon the electrons within the field free space between grids **2** and **3** is substantially that which would result had a theoretically perfect voltage been applied to a control grid between the cathode and anode of a tube. Thus as a result of the specific arrangement of the control grids and other electrodes and their associated circuits, a tube is provided which will function like a nearly theoretically perfect sharp pulse tube. As the period of absorption is comparatively short, the resulting pulse can be applied to a resonant circuit whose natural frequency is high. This would also permit a frequency multiplication to be obtained very easily.

However, in the present arrangement the anode **4** is placed at an angle to the other electrode in the tube so as to practice applicant's present invention, the other electrodes described being utilized to obtain the compressed mass of electrons advancing with a parallel front and having a depth small in comparison to the wavelength of the frequency of the voltages applied to the control electrode by the voltage source **9**.

The electrodes **2** and **3** may be in the form of narrow rectangles, for instance, the longitudinal sides of which, being indicated schematically in the drawing in the form of a solid line, are large compared to a quarter wave length

$$\frac{\lambda}{4}$$

of the oscillation to be produced. The antenna **5** is connected to that side of the anode arranged at a greater distance from the grid-shaped electrode **3**. The anode **4** is connected, through a resistance **6**, to a source **8** of direct current so as to have a potential ξ which is high with respect to that of the electrode **3** and the cathode **1**. The resistance **6** is of the same magnitude as the surge impedance of the conductor system formed by the electrodes **3** and **4** and their connections. The antenna **5**, the resistance of which is symbolized at **7**, is matched to the surge impedance of the conductor system **3**—**4** so that, in the manner which will be described below in greater detail waves can be produced which travel on along the electrodes **3** and **4** in the direction towards the antenna **5**, and increase in amplitude during this travel, due to further electron groups arriving during this travel, without causing disturbances due to reflections at the ends. If a "compression" of the electrons is effected in the manner described in my copending application by differently accelerating the electrons discharged from the cathode **1** in accordance with their different starting phase, by the "compressing" or "compacting" voltage existing on the electrodes **2** and **3**, the electrons will be compressed in the space between the grids **2** and **3** where no field exists, and move through the electrode **3**, towards the electrode **4**, in the form of a front of electron groups which is parallel to the electrode **3** and has a very small depth. Due to the inclination of the anode with respect to the grid **3**, the front of electrons will at first reach those parts of the anode which are nearest the electrode **3**, but remote from the antenna connection, while the front of electrons will arrive at the latest at the position of the anode near the antenna connection.

The discharge of each elementary strip will thus produce an elementary impulse on the anode and in the antenna which is connected thereto. The correct angle between the electrodes **4** and **3** or the anode **4** and the front of the electron group, respectively, will exist in accordance with the invention, if all of the sharply defined ends of current-impulses which are produced in the antenna by the portions of the front of the electron groups arriving at the anode, are united to a single sharply defined im-

pulse end. In a conductor system which is long in relation to a quarter wave length (the conductor system formed by the anode surface 4 on the one hand and the electrode 3 on the other hand and their connections), the time of propagation of the impulses, which are propagated along this conductor approximately at the velocity of light "c," will play an important part provided that the frontal speed $v=6.10^7\sqrt{\epsilon}$ of the electron groups is not too small in the neighbourhood of the anode. Fig. 1b shows the system in the moment where the left hand side of the front 10 of the electron group which is parallel to the electrode 3 and the depth of which must be small with respect to the value

$$\frac{\lambda}{2}\cdot\frac{v}{c}$$

and has been assumed to be infinitely small, for simplicity's sake, has nearly arrived at the anode 4. The end of the impulse of this side will then travel along the anode and arrive at the right hand side, at the antenna tap 5, when the right hand side of the electron front arrives at the anode 4. Assuming (although this is not quite accurate and will be corrected below) that the speed v in the neighbourhood of the anode is approximately constant for the whole front, or, $v=6.10^7\sqrt{\epsilon}$, the angle formed between the surfaces of the electrodes 3 and 4 will have to be equal in the first degree of approximation to the value

$$\frac{v}{c}$$

Thus, the voltage impulse between the electrodes 3 and 4 will proceed in the longitudinal direction of the electrodes 3 and 4, with the velocity c of light, towards the antenna provided that reflection of the wire waves at the two ends of the system is avoided by closing the system by a resistance equal to the surge impedance 6 and 7. On the antenna side the wave resistance 7 which has been shown in Fig. 1a in dotted lines, can be formed by the impedance of the antenna 5 proper. The impulse received by the anode and flowing to the left, or away from the antenna, during the period of absorption of the electron front by the anode represent a continuous current which can flow off through the resistance 6. In order to correct the inaccuracy contained in the above mentioned explanations, it must be considered additionally that the speed of the front is partly less than above stated, since, due to the oblique position of the anode the distance between the grid 3 and the anode 4 is greater on the right and the accelerating field is less intensive at this side. Therefore, strictly speaking, the front 10 is no more parallel to the electrode 3 in the neighbourhood of the anode. Of course the intersecting angle between the anode 4 and the front 10 remains

$$\alpha=\frac{v}{c}$$

but the anode has a different angle

$$\alpha'\approx\frac{\alpha}{2}=\frac{v}{2c}$$

with respect to the grid surface 3.

In the embodiment shown in Fig. 1a it has been assumed that the electrons are emitted from the cathode 1. In this case, the voltage produced by the source 9 is preferably not a sine wave voltage, but consists of a periodical function rising gradually from zero to a maximum and then falling back to zero very rapidly. However, in the practice of my invention, I prefer the use of a perforated electrode as a "quasi-cathode" through which the electrons, emitted from a preliminary control space, enter with small velocity into the space between the electrode 1 and the grid 2. In this case, the grid voltage (9) may be a sine wave voltage which is superposed on a constant grid bias, in the manner described in my copending application. In the example described in said copending application, the conditions in the preliminary control space have been assumed to be quasi-stationary. This is admissible provided that the frequency of repetition of the exciting impulse or shock is substantially smaller than the excited frequency and that its quarter wave length is larger than the longitudinal extension of the electrodes.

It will thus be understood that the invention may be characterised by the following features which are common to the above described example and to all other embodiments of the invention.

1. The depth of the front of electrons proceeding towards the anode must be equal to or smaller than the amount

$$\frac{\lambda}{2}\cdot\frac{v}{c}$$

This is substantially the condition underlying my copending application.

2. The width of the front and the length of the electrodes is equal to or substantially larger than a quarter wave length

$$\frac{\lambda}{4}$$

3. In order to meet the condition of summing up of the partial impulses to a total impulse, or, more strictly speaking, of coincidence of the sharply defined ends of the impulses, the intersecting angle α between the anode and the front must be approximately equal to

$$\frac{v}{c}$$

at least in the point of intersection formed by the electron front and the anode surface. In case of other than plane systems, such as cylindrical systems, the angle between the normals of the surfaces is the determining factor.

4. The antenna is connected to that point of the anode which is last reached by the electron front.

In the process of producing strong and sharply defined shocks or impulses for the shock excitation of short waves, the frequency of the oscillation which is produced will usually be a multiple of the frequency of repetition of the impulses which are required for the compression or concentration of the electron groups. The non-quasi-stationary conditions, of course, in many instances, and also in the present instance, exists in the anode space only. However, since very high frequencies of repetition are required for the impulses in order to produce very high frequencies, without a very high frequency multiplication it may also occur that non-quasi-stationary conditions exist in the spaces required for the compression or collection or in the preliminary control spaces.

Figs. 2a and 2b show a system which is adapted for non-quasi-stationary conditions in the preliminary spaces which are required for the preliminary control and for the compression. The valve 52 shown in Fig. 2a comprises a preliminary

control system including the heated cathode **21**, the preliminary control grid **22**, a positive grid **23** and the quasi-cathode **24** through which the preliminary controlled electrons enter into the compression system including the grid electrodes **25** and **26** which are interconnected, within the valve, by a conductor **41**, and into the main discharge space which is formed by the grid electrode **26**, the anode **27** which may be perforated if desired and the collecting plate **28**. Contrary to the arrangement according to my copending application, in which it has been assumed that quasi-stationary conditions exist, it is now assumed that voltage waves proceed both, between the electrodes **21** and **22** and between the electrodes **24** and **25**, in the longitudinal direction of the electrodes and with the velocity c of light, the phases of which voltage waves are relatively selected in such a manner that the electrons released or discharged by the proceeding wave at **21** pass through the electrode **24** in the very moment where the voltage wave in the preliminary control space in each associated elementary strip just shows the rising of the amplitude which rising is required for the compression. In Fig. 2*a*, a source of alternating voltage **29** and a source of direct current voltage **42** are connected in series to the grid **22**. Further, a source of alternating voltage **30** and a source of direct current voltage **44** are interposed in series between the electrodes **24** and **25**. **31**, **32**, **33**, **34**, **35**, **36** and **37** are resistances equal to the surge impedances required for avoiding reflection at the ends of the electrodes or for matching the antenna impedance to the conductor system. The antenna including its connecting wire is shown at **38**. The actions in each elementary strip is exactly the same as described in my copending application, while the progressing character of the actions will be noted when considering the whole unit of the parallelly positioned elementary strips and the phase difference between the single strips. Due to the progressing release of electrons in the preliminary control and compression space the front of the electron groups enters into the anode space in such a manner that it forms, at least in the neighbourhood of the anode **27**, the angle

$$\alpha = \frac{v}{c}$$

with respect to the anode, and the anode is parallel to the electrode **26**. Assuming, for instance, a perforated anode **27**, the electron front passes through the anode **27** at the angle α. The total course of the electron front **40** is shown in Fig. 2*b*, which illustrates the moment where approximately one-half of the front **40** has passed the anode **27**. This front passes through the anode approximately with the speed

$$v = 6.10^7\sqrt{\epsilon}$$

while the impulse proceeds from the left to the right with the velocity of light c.

It will thus be understood from the foregoing that the general idea underlying my invention resides in the fact that in the use of electronic tubes for the shock excitation of oscillations the wave length of which is of the order of the greatest dimension of the discharge cross section or even substantially smaller, the temporal compression, as disclosed in my copending application, will not be sufficient to obtain high efficiency. In this case the potential on the anode is no longer quasi-stationary. The electron groups passing over in a compressed state in each discharge strip, or in each tubular elementary discharge path which is parallel to the discharging direction, must arrive at different times at the anode for reaching the antenna all at the same time by proceeding along the anode. The term "anode" of course designates always that electrode which among the electrodes connected to the oscillatory circuit has the highest positive voltage so that, as the electrons enters into or passes through the electrode, the greatest change of the current influenced by the electrons is produced. The anode may be in the form of a solid or perforated electrode. Accordingly, in the latter case the "absorption time" will be the time of passage of the electron groups through the perforated anode.

The discharge of electrons causes an absorbing action proceeding along the anode. This proceeding absorbing action may be effected by the provision of an anode which is inclined with respect to the front of the electron groups provided that the alternating fields in the preliminary control and compression spaces as to their amplitude and phase are constant along the electrodes of these spaces. In this case the front of the electron groups will be substantially parallel to these electrodes and the normal to the anode surface accordingly must form an angle with respect to the normal of the electrode immediately preceding the anode which is at least equal to the ratio of half the electron speed at the anode to the velocity of light.

The anode may be subdivided or split up into a plurality of partial anodes, as shown by way of example in Fig. 3. The arrangement according to this figure is substantially the same as that shown in Fig. 1*a* and the same reference numerals have been used, except that a modified form of anode has been shown. The modified form of the anode serves two different purposes. If the systems are made very long in a longitudinal direction, the inclination of the anode surface would cause a too large electrode distance at the antenna end of the anode and the current intensity of the impulses would be weakened. This reduction of the impulse intensity can be avoided by the subdivision of the anode into a plurality of partial oblique anodes having advantageously a longitudinal extension of about one wave length, which anodes are connected to form a stepped anode **54** as indicated in Fig. 3. The subdivision of the anode at the same time offers the advantage that partial impulses are produced in the antenna **5** the temporal distance between which is by a multiple smaller than the temporal distance of the electron fronts which follow each other periodically. While the electron front reaches all homologous points simultaneously, the impulses produced thereby reach the antenna **5** at different times in accordance with their finite speed of propagation along the staggered or stepped anode. This is very important for the frequency multiplication, since the impulse to be multiplied is thereby transformed into oscillations of a higher frequency and constant amplitude.

The oblique direction of the electron front with respect to the anode may also be produced by the provision of different field forces in the anode space. An acceleration of the electrons which decreases along the system towards the antenna side may be effected by variation of the direct voltage along the anode (anode of resistance material) or by varying the action of the anode

voltage through the openings of the immediately preceding electrode, which action decreases towards the antenna. In view of the small value

$$\frac{v}{c}$$

these variations of the field forces or intensities are also small.

It is also possible to control the discharge in such a manner that a front of electron groups is produced which is inclined with respect to the anode while the latter is parallel to the remaining electrodes. The interaction of this inclined front of electron groups with the anode causes a progressing absorbing action along the anode. This will occur if the preliminary control and compression voltages produce also voltage waves on the electrodes of the control spaces which proceed along said electrodes. In this case the electrodes may be all positioned substantially parallel, for example, plane or cylindrical. As pointed out above, the progressing absorbing action is rendered possible in the anode region by the fact that reflections at the ends of the space which is limited by the anode and the electrodes immediately adjacent thereto are avoided. The same applies with respect to the preliminary space and the position of the source of alternating voltage and of the matched resistances follows from the direction of progress of the waves. The sources of voltage producing the preliminary control and compression voltages are placed on one side of the system, for example, the left hand side, while the corresponding surge impedances are placed on the opposite or the right hand side, so that the waves produced in the preliminary control and compression regions can proceed only along these electrodes, without any reflection which would disturb the smooth proceeding action. Accordingly the antenna is connected to that side of the anode which is opposite the side of the conductor system connected to the control voltage, or the right hand side (Fig. 2*a*).

The conductor system consisting of the anode and its adjacent electrode is advantageously closed at the end on the antenna side by the matched antenna. The length of the conductor system is an integral multiple of

$$\frac{\lambda}{4}$$

The direct current outlet of the anode is advantageously arranged on the side of the anode opposite to the antenna connection. While the discharge impulses which arrive on the anode in temporal succession are superimposed to the total impulse, in the direction of progress of the impulse, a continuous current flows in an opposite direction during the time where the individual elementary charges are absorbed by the anode. It will thus be understood that the method according to the present invention comprises the accommodation of the method described in my copending application for the temporal compression of electrons which are emitted from the cathode in longer periods of time, to a charge which is temporally compressed or compacted, to discharge systems which cannot be regarded as quasi-stationary. The electron groups subjected to the temporal compression in each cross sectional element impinge on the anode at different points and at different times, in such temporal intervals from cross section to cross section, that the ends of the current impulses produced thereby coincide with each other or are in phase, respectively. As a result, a sharply defined current impulse is produced in the antenna for exciting a very short oscillation therein. In this manner, the dimensions of the electrode systems are not limited by the wave length. The invention permits the use of electrode systems which are long compared to the wave length. The electrode system according to the invention may be regarded as an conductor system with a continuously distributed negative resistance or electromotive force in which the amount of output is proportional to the length of the system.

I claim:

1. An electron discharge device having a cathode for emitting electrons and an anode for collecting said electrons, control electrode means intermediate the cathode and anode, means for applying to the control electrode means alternating voltages for compressing the electrons from the cathode into successive groups of electrons having an extended front but of a depth less than one-quarter the wavelength of the frequency of the applied alternating voltages times the ratio of the velocity of the electrons to the speed of light, said anode being positioned so that the electrons approach the absorbing surface of the anode at an angle to be progressively absorbed from one end of the anode to the other.

2. An electron discharge device having a cathode for emitting electrons and an anode for collecting said electrons, control electrode means intermediate the cathode and anode, means for applying to the control electrode means alternating voltages for compressing electrons from the cathode into successive groups of electrons having an extended front but of a depth less than one-quarter the wave length of the frequency of the applied alternating voltage times the ratio of the velocity of the electrons to the speed of light, said anode being positioned so that the electrons approach the absorbing surface of the anode at an angle to be progressively absorbed from one end of the anode to the other, said anode having a length greater than one-quarter the wavelength of the frequency of the applied alternating voltage.

3. An electron discharge device having a cathode for emitting electrons and an electrode for collecting said electrons, control electrode means intermediate the cathode and collector electrode, means for applying to the control electrode means alternating voltages for compressing electrons from the cathode into successive groups of electrons having an extended front but of a depth less than one-half the wavelength of the frequency of the applied alternating voltage times the ratio of the velocity of the electrons to the speed of light, said collector electrode being positioned so that the electrons approach the absorbing surface of the collecting electrode at an angle to be progressively absorbed from one end of the collecting electrode to the other.

4. An electron discharge device having a cathode for supplying electrons and a collector for said electrons, a first control electrode and a second control electrode providing a field free space positioned between the cathode and collector, and means for applying to said control electrodes variable voltages for compressing electrons from the cathode into successive groups of electrons having a front comparable to the dimensions of the collector but of substantially no depth, said collector being positioned so that the electrons approach the surface of the anode at an angle whereby the compressed electrons

are collected successively along the length of the collector.

5. An electron discharge device having a cathode for supplying electrons and an anode for receiving energy from said electrons, a first control electrode and a second control electrode providing a field free space positioned between the cathode and the anode, and means for applying to said control electrodes variable voltages for compressing electrons from the cathode into successive groups of electrons, each group having an extended front of substantially little depth, said anode being positioned so that the electrons approach the surface of the anode at an angle, the electrons reaching the surface of the anode in succession along the length of the anode, and an impedance connected between the anode and the second control electrode, and a radiator electrically connected to the end of the anode last to be reached by the advancing electron front.

6. An electron discharge device having a cathode for supplying electrons and a collector electrode for said electrons, a first control electrode and a second control electrode providing a field free space positioned between the cathode and collector electrode, and means for applying to said control electrodes variable voltages for compressing electrons from the cathode into successive groups of electrons each group having a front comparable to the dimensions of the collector electrode but of substantially no depth, said collector electrode being positioned so that the electrons approach the surface of the collector electrode at an angle whereby the electrons are collected by the collector electrode in succession along the length of the collector electrode, and an impedance connected between the collector electrode and one of said control electrodes equal to the impedance between the collector electrode and the control electrode, and a radiator electrically connected to the end of the collector electrode last to receive electrons from an advancing electron group.

7. An electron discharge device having a cathode for emitting electrons, a first control electrode, a second control electrode providing a field free space, and an anode in the order named, means for applying to one end of said first control electrode a voltage such that electrons will flow through said first control electrode discontinuously and other means for applying to one end of said second control electrode a variable voltage having a rising positive characteristic at that time when electrons which have passed through the first control electrode come under the influence of said second control electrode for accelerating said electrons through the field free space for causing said electrons to be compressed within said field free space to provide an advancing group of electrons of extended front but of little depth, said anode being positioned to receive at an angle the advancing front of each group of electrons to receive energy from said electrons successively from one end of the anode to the other, and an impedance connected between one cathode and the end of the first control electrode remote from the end to which voltage is supplied, and a second impedance connected between the second control electrode and the anode at the end remote from the end to which the variable voltage is applied, and a radiator connected to the end of the anode to which said impedance is connected.

8. An electron discharge device having a cathode for emitting electrons, a first control electrode, a second control electrode providing a field free space and an anode in the order named, means for applying to said first control electrode a voltage such that electrons will flow through said first control electrode discontinuously, and other means for applying to said second control electrode a variable voltage having a rising positive characteristic at that time when electrons which have passed through the first control electrode come under the influence of said second control electrode for accelerating said electrons through the field free space for causing said electrons to be compressed within said field free space to provide an advancing group of electrons of substantially no depth, said anode being positioned to receive at an angle the advancing front of the group of electrons to receive energy from said electrons successively from one end, and a radiator connected to the end of the anode last to receive energy from the advancing electron group, and an impedance connected between the other end of the anode and the second control electrode.

9. An electron discharge device having a cathode for emitting electrons, a first control electrode, a second control electrode providing a field free space and an anode in the order named, means for applying to one end of said first control electrode a voltage such that electrons will flow through said first control electrode discontinuously and other means for applying to one end of said second control electrode a variable voltage having a rising positive characteristic at that time when electrons which have passed through the first control electrode come under the influence of said second control electrode for accelerating said electrons through the field free space for causing said electrons to be compressed within said field free space to provide an advancing group of electrons of extended front but of little depth, said anode being positioned to receive at an angle the advancing front of each group of electrons to receive energy from said electrons successively from one end of the anode to the other and an impedance connected between one end of the cathode and the end of the first control electrode remote from the end to which voltage is supplied, and a second impedance connected between the second control electrode and the anode at the end remote from the end to which the variable voltage is applied, and a radiator connected to the end of the anode to which said impedance is connected, said control electrodes and said anode having a length greater than one quarter of the frequency of the voltage applied to said second control electrode.

10. An electron discharge device having a cathode for supplying electrons, a first control electrode and a second control electrode comprising a pair of spaced grid members electrically connected together for providing a field free space therebetween, and an anode, a circuit for applying to said first control electrode a voltage such that the electrons will flow through said first control electrode discontinuously, and a second circuit for applying to said second control electrode a variable voltage increasing in a positive direction at the time when electrons which have passed through said first control electrode come under the influence of the second control electrode, the electrons being compressed within the field free space of said second control electrode into groups of substantially little depth, and a collector positioned on the outside of the anode and impedances connected between the second

control electrode and the anode at both ends of said second control electrode, and a radiator connected to one end of said anode, and an impedance connected between the cathode and the first control electrode.

11. An electron discharge device having a cathode for supplying electrons, a collector electrode, a first control electrode and a second control electrode bounding a space for providing a field free space between the collector electrode and cathode, and shielding means between said first and second control electrodes, a circuit for applying to said first control electrode a voltage such that the electrons will flow discontinuously through said first control electrode, and a second circuit for applying to said second control electrode a variable voltage increasing in a positive direction at the time when the electrons come under the influence of the second control electrode, the electrons being accelerated by said second control electrode and grouped within the field free space of said second control electrode whereby said electrons become compressed into an advancing electron front of substantially little depth, and an output electrode positioned between the second control electrode and the collector electrode and impedances connected between the second control electrode and the output electrode at both ends of said second control electrode and output electrode, and a radiator connected to the output electrode, said control electrodes and said output electrode being greater than quarter wavelength of the frequency of the voltage applied to said second control electrode.

12. An electron discharge device having a cathode for supplying electrons, a collector electrode, a first control electrode and a second control electrode bounding a space for providing a field free space between the collector electrode and cathode, and shielding means between said first and second control electrodes, a circuit for applying to said first control electrode a voltage such that the electrons will flow discontinuously through said first control electrode, and a second circuit for applying to said second control electrode a variable voltage increasing in a positive direction at the instant of time when the electrons come under the influence of the second control electrode, the electrons being accelerated by said second control electrode and grouped within the field free space of said second control electrode whereby said electrons become compressed into an advancing electron front of substantially little depth, and an output electrode positioned between the second control electrode and the collector electrode and impedances connected between the second control electrode and the output electrode at both ends of said control electrode and output electrode, and a radiator connected to the output electrode.

13. An electron discharge device having a cathode for supplying electrons, a collector electrode, a first control electrode and a second control electrode bounding a space for providing a field free space between the collector electrode and cathode, and shielding means between said first and second control electrodes, a circuit for applying to said first control electrode a voltage such that the electrons will flow discontinuously through said first control electrode, and a second circuit for applying to said second control electrode a variable voltage increasing in a positive direction at the time when the electrons come under the influence of the second control electrode, the electrons being accelerated by said second control electrode and grouped within the field free space of said second control electrode whereby said electrons become compressed into an advancing electron front of substantially little depth, and an output electrode positioned between the second control electrode and the collector electrode and impedances connected between the second control electrode and the output electrode at both ends of said second control electrode and output electrode, and a radiator connected to the output electrode.

14. An electron discharge device having a cathode for emitting electrons, a first control electrode, a second control electrode and a collector electrode in the order named, means for applying a voltage to said first control electrode such that electrons will flow through said first control grid discontinuously, and other means for applying to said second control electrode a variable voltage having a rising positive characteristic at that period of time when electrons come under the influence of said second control electrode, and providing a field free space between said second control electrode and said anode for causing electrons to be compressed within said field free space so as to have an electron front of extended area but substantially no depth, said collector electrode consisting of a plurality of electrically connected sections, each of the sections being parallel to the other sections but positioned at an angle to the surface of the other electrodes between the cathode and collector.

15. An electron discharge device having a cathode for supplying electrons, a first control electrode and a second control electrode surrounding a space to provide a field free space, and an anode, a circuit for applying to said control electrode a voltage such that electrons will flow through said first control electrode discontinuously and a second circuit for applying to said second control electrode a variable voltage increasing in a positive direction at a time when electrons which have passed through said first control electrode come under the influence of said second control electrode, said electrons being compressed in the field free space of the second control electrode in groups of substantially little depth, a screen electrode positioned between said first and second control electrodes, and impedances connected between the cathode and first control electrode and the anode and second control electrode, and an impedance connected between the screen and first control electrode, and a radiator connected to said anode.

16. An electron discharge device having a cathode for supplying electrons, a first control electrode and a second control electrode surrounding a space to provide a field free space, and an anode, a circuit for applying to said control electrode a voltage such that electrons will flow through said first control electrode discontinuously and a second circuit for applying to said second control electrode a variable voltage increasing in a positive direction at a time when electrons which have passed through said first control electrode come under the influence of said second control electrode, said electrons being compressed in the field free space of the second control electrode in groups of substantially little depth, and impedances connected between the cathode and first control electrode and the anode and second control electrode, and a radiator connected to said anode.

17. The method of operating an electron dis-

charge device which comprises generating electrons, subjecting the electrons to an alternating current field to permit the passage of only a small group of electrons through said field during each cycle, subjecting the group of electrons to a variable electric field increasing in intensity in a positive direction for a short period of time to variably accelerate the electrons within the group, passing said group of electrons through a field free space for causing the fast and slow electrons to combine into compressed groups having an extended front but of little depth, and utilizing the compressed group of electrons to provide a sharp pulse for causing high frequency oscillations by absorbing the energy of the electrons successively from one end of the extended front to the other.

18. The method of operating an electron discharge device which comprises continuously generating electrons, subjecting said electrons to an alternating current field to permit passage of electrons during only a part of the cycle of the applied voltage, directing said electrons through a shielded space, subjecting said electrons to a variable electric field while said field is increasing in intensity in a positive direction to variably accelerate said electrons, passing said electrons through a field free space whereby the fast electrons overtake the slow electrons to form compressed groups of electrons having an extended front but of little depth, and utilizing the compressed electrons to provide sharp pulses in a utilization circuit by causing said electrons to approach an output electrode at an angle thereto whereby energy is transferred from the group of electrons successively along the output electrode from one end of the electrode to the other to impose upon the energy already absorbed by the output electrode the remaining energy of the electron group as the front of electrons approaches the output electrode.

19. The method of operating an electron discharge device which comprises generating a constant flow of electrons, subjecting said electrons to an alternating field for permitting said electrons to flow through said field discontinuously to form successive groups of electrons, subjecting each group of electrons to a second field having a rising positive voltage characteristic at the time when said group enters said second field for accelerating the electrons as they enter the field, the last to enter the field being accelerated to the greater extent, passing said electrons through a field free space to accentuate the grouping of the fast and slow electrons of each group to form a compressed group of electrons having an extended front, and absorbing said electrons successively from one end of said extended front to the other along an absorption surface to produce a sharp pulse and causing high frequency oscillations by use of said pulses.

20. A method of operating an electron discharge device which comprises continuously generating electrons, subjecting the electrons to an alternating current field whereby groups of electrons are made to pass through said field discontinuously, subjecting each group of electrons to a second alternating current field during that period when the field intensity is increasing in a positive direction to variably accelerate the electrons in said group, passing said electrons through a field free space to cause the fast electrons to overtake the slow electrons in the field free space to provide compressed groups of electrons having an extended front of substantially little depth and utilizing the compressed group of electrons by causing said electrons to approach a conducting surface at an angle thereto whereby energy is transferred from the group of electrons successively along the conducting surface from one end of the extended electron front to the other to successively add to the energy already absorbed by the conducting surface as the electrons approach the conducting surface and utilizing the energy absorbed by the surface to cause high frequency oscillations.

GÜNTHER JOBST.